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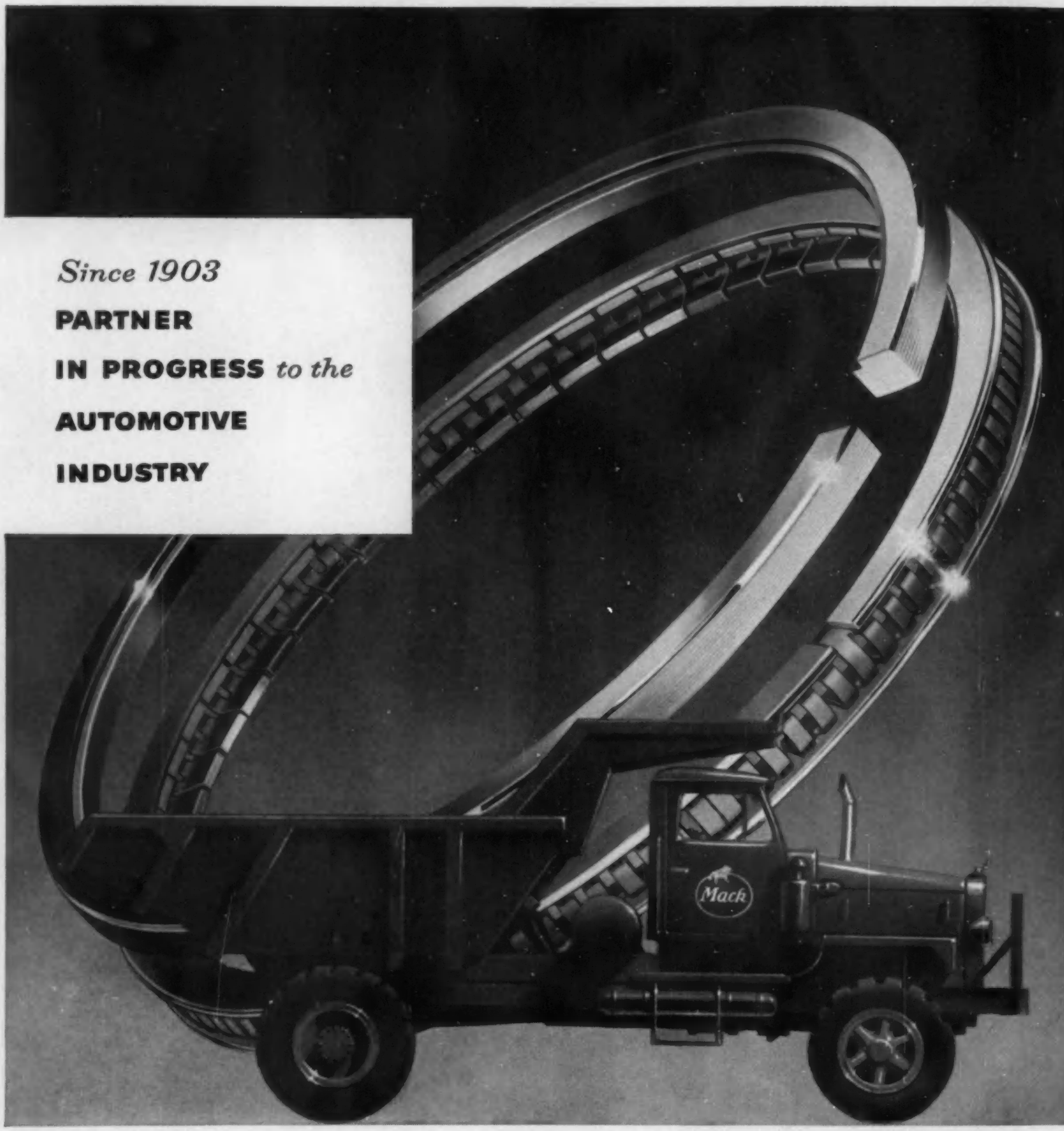
SAE Journal

APRIL 1958

IN THIS ISSUE . . .

Published by The Society of Automotive Engineers



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SAE journal

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SAE JOURNAL, April, 1958, Vol. 66, No. 4. Published monthly except two issues in January by the Society of Automotive Engineers, Inc. Publication office at 10 McGovern Ave., Lancaster, Pa. Editorial and advertising department at the headquarters of the Society, 485 Lexington Ave., New York 17, N. Y. $1 per number; $10 per year; foreign $12 per year; to members 50¢ per number, $3 per year. Entered as second class matter, Sept. 15, 1948, at the Post Office at Lancaster, Pa., under the act of Aug. 24, 1912. Acceptance for mailing at special rate of postage provided for in the Act of Feb. 28, 1925, embodied in paragraph (d-2), Sec. 34.40, P. L. and R., of 1918. Additional entry at New York, N. Y.

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AIRCRAFT

Requirements of Missile Industry for Accessory Power, R. D. BOYNE. Paper No. 215 presented Sept.-Oct. 1957, 9 p. Requirements reviewed from both technical and financial standpoints; 10-yr forecast of yearly procurement dollars to be spent on devices such as batteries, hot gas servos, turbine types, etc; chart of power levels; methods of producing accessory power; areas where large percentage of funds will be spent; suggestions on how to solve problems within confines of financing conditions.

High Speed Aircraft Design for Good Spin Characteristics, J. K. WYKES. Paper No. 227 presented Sept.-Oct. 1957, 10 p. Although spin is secondary design requirement, there are design factors coinciding with higher priority considerations; design for good spin characteristics as part of overall design of military aircraft, etc; trends in mass and aerodynamic design; relationship between inertia roll coupling and spin problem; analysis and design tools available; application of mass and aerodynamic design parameters.

Integration of Electronic Systems with Airframe Design, N. C. HARNOIS. Paper No. 228 presented Sept.-Oct. 1957, 8 p. Need to consider operational requirements of entire system; these factors form foundation for other decisions such as mounting, packaging, cooling accessibility, maintainability and reliability; design philosophy applied to Lockheed's F-104 Starfighter in integrating into airframe electronics installation including communication, navigation and other components; use of "jeep can" packaged electronic equipment.

How Badly Are High Temperature Electronic Systems Really Needed? R. R. JANSSEN. Paper No. 230 presented Sept.-Oct. 1957, 9 p. Forecast of environmental temperatures to be expected for future years up to 1962; how they are related to weight penalties for cooling; it is shown that average weight increase for temperature improvement of electronic element should be held to less than 15–30%; figure is based on supersonic mission time of about 1 hr and on increase of temperature resistance to 500–600 F range.

Latest Developments in VTOL Aircraft, J. A. O'MALLEY, JR. Paper No. S35 presented Sept. 1957 (Buffalo Sec) 14 p. Some of experience and progress of Bell Aircraft Corp. in research on various VTOL configurations ranging from helicopter to after-burning turbojet types particularly those capable of very high forward speeds; approach by Bell represents principally rotating thrust type; experimental tests on stability and control; application of rotating thrust line concept to X-14 fighter.

COMPUTERS

Electronic Computer—Newest Engineering Tool, D. G. THOROMAN. Paper No. S40 presented Nov. 1957 (Dayton Sec) 3 p. Areas of computer applicability to engineering problems are as follows: engineering design, model simulation, data reduction, statistical computations, operations research and management science; relative cost of different computers are tabulated; FORTRAN (formula translation) automatic coding system for IBM 704 which translates algebraic statements into computer instructions.

FUELS & LUBRICANTS

Improvements in Motor Fuels, W. G. AINSLEY. Paper No. S32 presented Nov. 1957 (Atlanta Sec) 10 p. Background of research work, and present methods in fuel improvement research including work of Cooperative Fuel Re-

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Briefs of SAE PAPERS

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search Committee of SAE on antiknock testing program and later developments; fuel problems associated with achievement of higher compression ratios, greater volumetric efficiency, and higher brake horse power; engine troubles due to effects of combustion chamber deposits; methods in screening of additives.

Effect of Oil Composition on Pour Reversion in Alaska and British Columbia, E. C. FOEHR, N. W. FURBY. Paper No. 251 presented Nov. 1957, 13 p. To determine stable pour point of engine lubricating oils and factors influencing fluidity during field exposure, winter field studies of pour reversion were made at Prince George, BC, and Fairbanks, Alaska; test procedures and results; accurate prediction can be made only with help of suitable stable pour cycle patterned after climatic temperature changes occurring in area where oils are stored.

Lubricant Factors Affecting Passenger Car Oil Consumption, J. K. PATTERSON, R. C. GREGOR. Paper No. 252 presented Nov. 1957, 27 p. Results of field tests on passenger car motor oils to determine lubricant factors affecting oil consumption; method developed is suitable for predicting consumption characteristics of finished oils of widely different viscosity indices from 100 to 150 VI and containing VI improvers with different shear breakdown and viscosity thickening characteristics, as well as non-VI-improved oils.

Heavy Duty Diesel Engine Lubricating Oils—Superior Lubricants (Series 3), J. W. VOLLENTINE. Paper No. 253 presented Nov. 1957, 7 p. Report on tests, undertaken by Research Dept of Caterpillar Tractor Co to evaluate contribution of additives and to study performance of Series 2 and Series 3 oils, destined for use in new high speed engines; in field tests $5\frac{1}{8} \times 6$ in. supercharged engine was used among others; tabular data showing test results.

Coking Tendencies of Lubricating Oils, F. G. ROUNDS, Paper No. 255 presented Nov. 1957, 31 p. Recent tests had indicated that panel coking test was not adequately screening oils submitted to WADC for qualification; therefore effects of test and oil variables were examined to determine whether proper selection of test conditions would result in better correlation with service experience for jet and other types of engines; results indicate usefulness of panel coker, but different test conditions may be required to obtain improved correlation.

Inter-Relationship of Fuel Constituents, Combustion Chamber Deposits, and Automotive Engine Performance. A. V. MRSTIK, R. B. PAYNE. Paper No. 257 presented Nov. 1957, 29 p. Results of studies to find best method for alleviating detrimental effects of deposits on performance; particulars of fuel and additive studies and techniques; fleet tests of tri-alkyl phosphines; mechanism of phosphine action; although its use reduces surface ignition, spark plug fouling and octane requirement buildup, further improvement is needed.

Correlations Between Road Octanes, Laboratory Octanes, and Hydrocarbon Type, W. E. MORRIS. Paper No. 261 presented Nov. 1957, 9 p. Correlations for prediction of road octane numbers from laboratory ratings and hydrocarbon types; results of tests to obtain Modified Uniontown ratings; Modified Borderline octane numbers; relative importance of Research and Motor octane numbers; olefin content, etc; tabulations of equations expressing various correlations.

Investigating Combustion Phenomena in Unmodified Engines, J. A. ROBISON, M. D. BEHRENS, R. G. MOSHER, J. M. CHANDLER. Paper No. 256 presented Nov. 1957, 13 p. To separate knock from other combustion phenomena in tests of unmodified engines, spark plug pressure indicator

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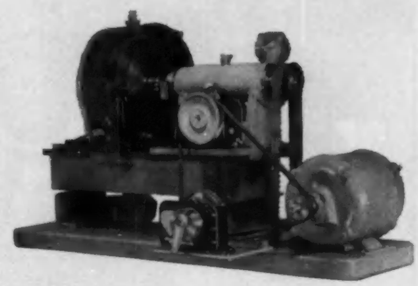

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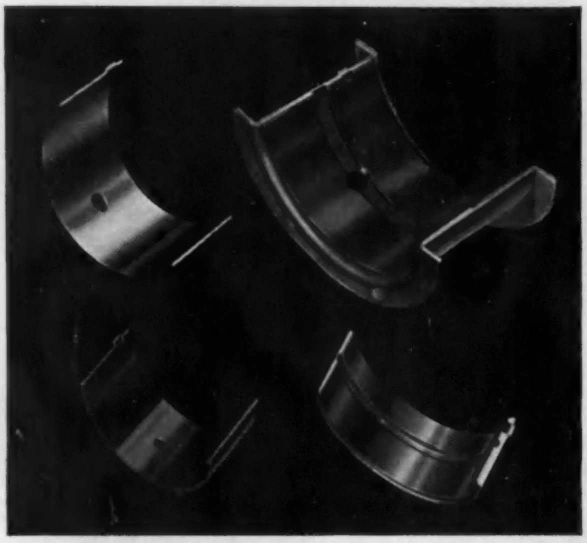

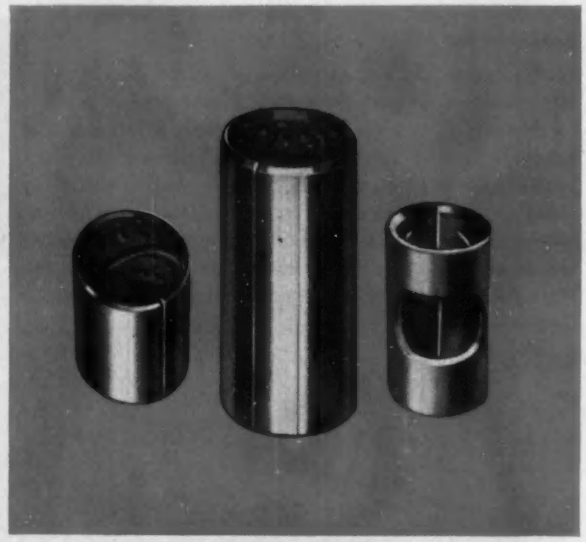

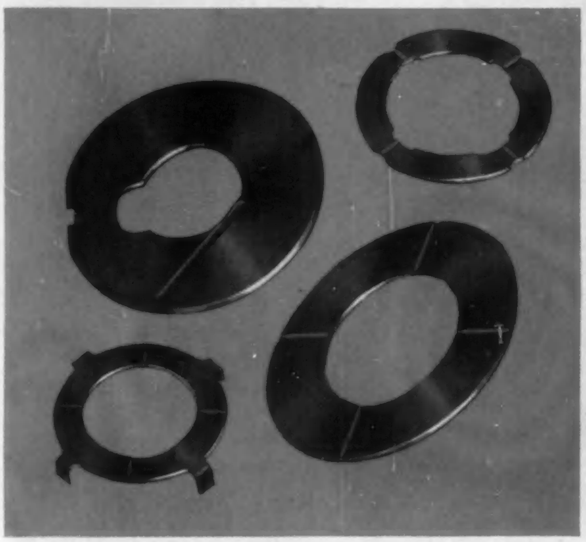

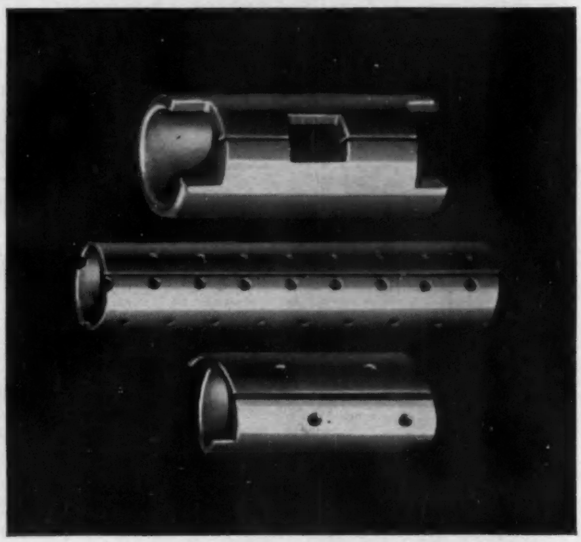

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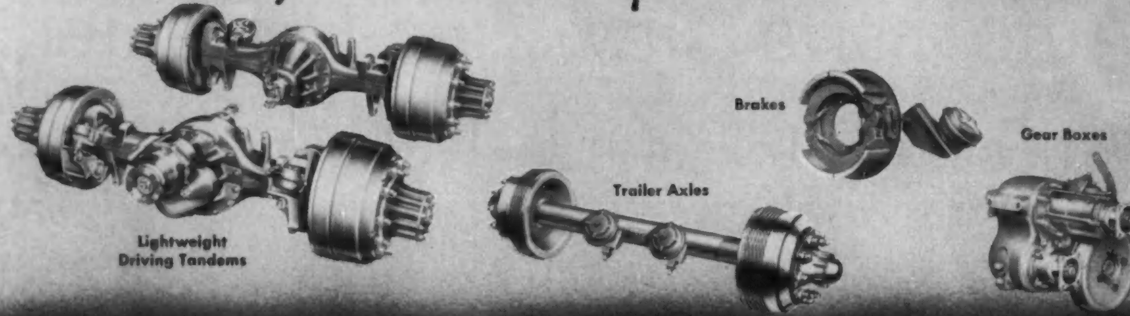

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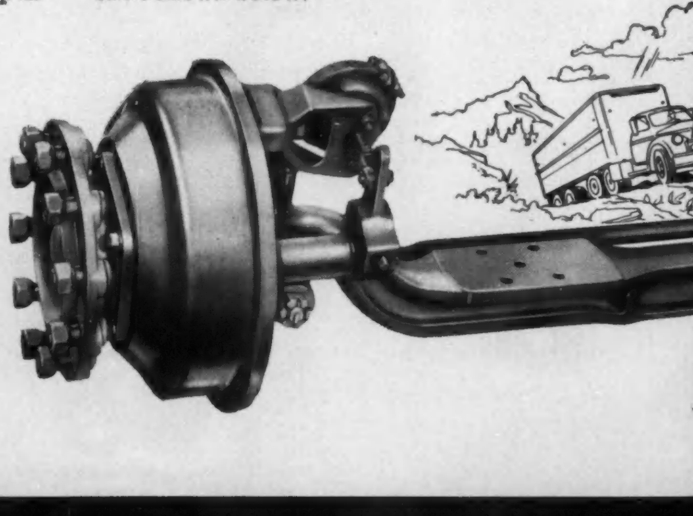
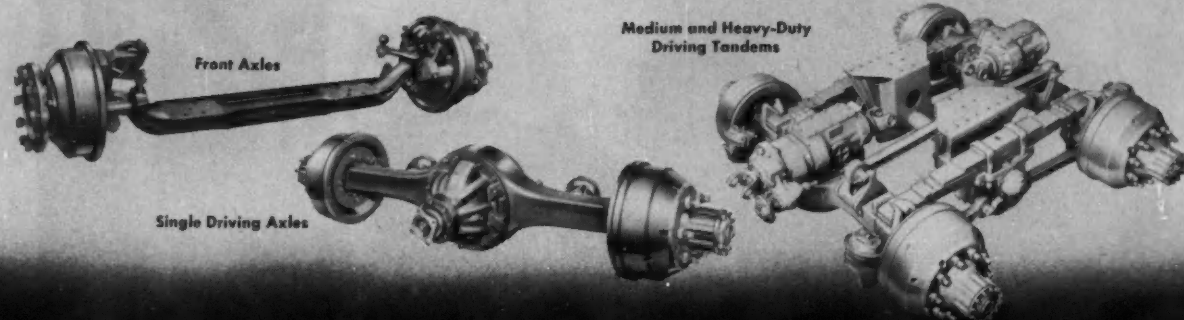


Axles and Brakes for Commercial Vehicles



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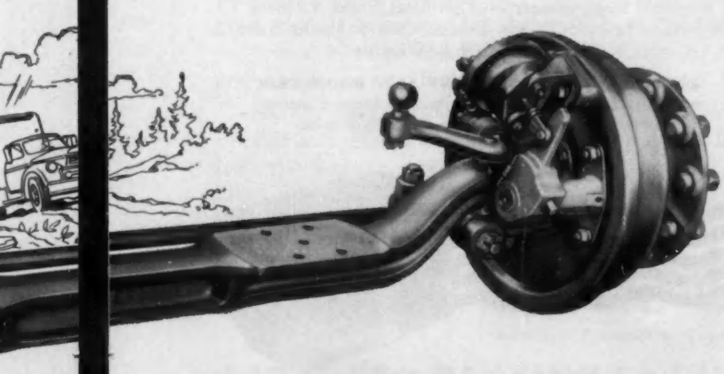

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For The Sake of Argument

Satisfied With Yourself?

By Norman G. Shidle

Satisfaction with one's self is at the opposite pole from self-satisfaction. Lack of the first means constant emotional discomfort; sometimes leads to disintegration of personality. Presence of the latter may mean these same things for everybody in contact with the self-satisfied.

That elusive thing we call "happiness" rarely roosts in the heart of a self-satisfied somebody. But it's not often absent in the consciousness of the fellow who acts as he really thinks.

Self-satisfaction provides no spur service—very little even to action. Satisfaction with one's self almost always results from active service to something or somebody else.

Of a man immune to suggestions, we're likely to say: "He's self-satisfied." When he works more for others than for his own, we're likely to discover that he is not chronically dissatisfied with himself.

Self-satisfaction is a dead-end street. The road to satisfaction with one's self is a free highway open for endless travel. One is a sort of isolated inertia; the other a living movement. (It may not be without significance that when we say "Rest in peace" we are usually referring to someone we think of as already dead.)

The true "happiness" or "peace" which accompanies satisfaction with one's self is available only NOW—never yesterday or tomorrow.

chips

from SAE meetings, members, and committees

IF YOU'VE been wondering about the effect of air conditioning on fuel requirements and engine performance, this may be the answer to your question. Obviously, air conditioning units require power that is derived from the car's engine. So it's reasonable to conclude overall performance of the vehicle will be affected. Studies recently completed give these results: (1) in every case, use of an air conditioning unit resulted in a loss of power delivered to the rear wheels, ranging from 1 to 5%, (2) there was a drop in fuel economy, ranging from 4 to 10%.

•

YOU may have failed to notice these significant facts about American motoring habits.

Approximately 85% of the mileage accumulated by the motorist today is short-run driving.

Average annual mileage per car is *de*creasing—from 9948 miles per car in 1946 to 9357 in 1956.

In 55% of all trips, the average car carries the driver only. Average load per trip, including children, is 1.80 passengers.

It has been estimated that in May, 1957, a total of 6,150,000 families owned two or more cars. This accounts for 24.3% of all privately owned passenger cars. The corresponding figure for 1948 was 6.66%.

•

"A BRIEF ON EXOTIC MATERIALS" is one of 12 panels scheduled for the SAE Aircraft Manufacturing Forum in Los Angeles next Fall.

"What's an exotic material?" somebody asked when the title was reported to the SAE Production Activity.

A. O. Smith's Sig Rudorf popped up with: "An exotic material is any material you can't machine."

DETROIT is developing another "proving ground" that is entirely unique. There are no high-speed test tracks or graded hills or Belgian blocks. In fact, the original investment in the newest Detroit testing ground is the cost of collecting precipitation data from January, 1949, through February, 1954.

During the early months of each of these years, pH of the collected precipitation reached values of 4 and 5, indicating the precipitation is strongly acid. For this reason, studies of the performance of plated parts in the Detroit area have been unusually helpful in developing specifications for plated automobile parts. Plated panels were exposed at Cleveland, Pittsburgh, Miami, and Detroit. The results showed corrosion at Detroit was the most severe of any of these cities.

•

AIRLINE ENGINEERS recently have cited a number of instances indicating the need for improvement in instrument accuracy. Among those cited were:

- A 1% error in the Mach meter can boost fuel consumption as much as 7%.
- A major airline has calculated that having a 12-min delay in each segment of each flight would cost it $1,700,000 per year.
- Aircraft whose volume fuel meters are calibrated for foreign fuels may be dangerously overloaded with cargo if they refuel in the United States and fail to account for the difference in specific gravities of kerosenes.
- Weight-measuring fuel meters may be off 1–4%. With modern transports, a 4% error in fuel measurement may be the equivalent of 5000 lb in payload.
- Altitude separation of 2000–4000 ft is needed for jets merely because accurate altimetry above 29,000 ft has not been available.
- Separation is going to be a real problem with jet transports because, with the turbine engine's sensitivity to altitude, every transport operating on a given day will want to fly at the same altitude—and, assuming a favorable jet stream, everyone going in the same general direction will want to take the same path.

•

ON THE NEW BUICK Flight-Pitch Dynaflow, there are lugs on the aluminum support that take the forward clutch reaction torque. During the durability testing, these lugs cracked off time and again.

Each design improvement helped, but it was not until die castings replaced the experimental sand castings that no more trouble was encountered. Moral, says a Buick engineer, "If the aluminum casting suppliers could produce prototype castings that had the fatigue characteristics of die castings without building costly production dies, a lot of ulcers would be saved in product engineering departments.

•

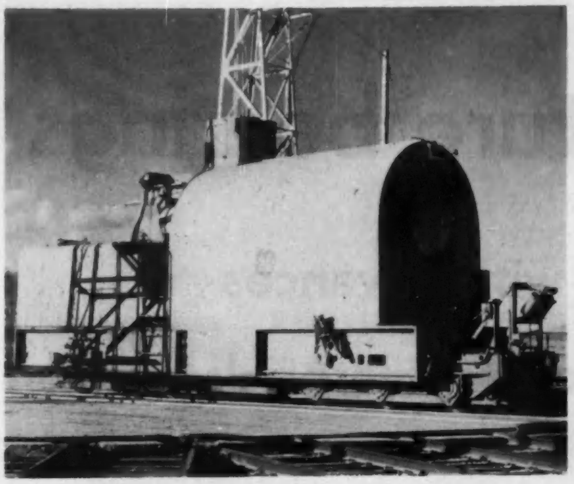
ANOTHER EARTH SATELLITE is Lockheed's Georgia Division potential — and unwanted — goal. The satellite may be a 4000 psi, 1000 F servo valve presently under test. While simulating aerodynamic pulses in the "block house" lab, the engineers have their fingers crossed that the pneumatic valve doesn't "go unstable."

•

SOMETIMES I wonder if we shouldn't call them "noise reversers and thrust suppressors," remarks one airlines engineer weary of the sound and stopping problems of the coming jet transports.

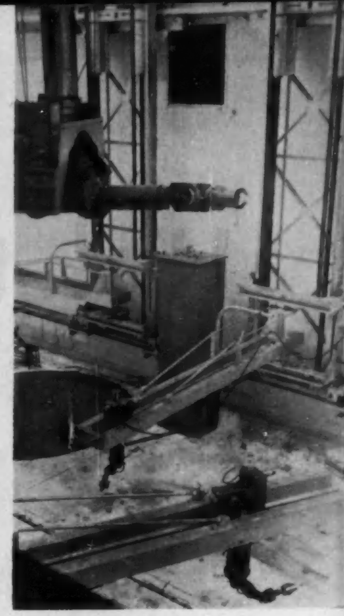
A feature of the
SAE Nuclear Energy Advisory Committee

Remote-Handling Tools Help Service Aircraft Nuclear Powerplants



THE POWERPLANT is assembled on a railroad flat car or dolly. A shielded locomotive, designed to protect operating personnel from radioactivity (shown above), transports the powerplant to the site of operation and then to the "hot" shop for remote disassembly.

THE "HOT" SHOP at the Idaho Test Station is 50 ft wide, 100 ft long, and 60 ft high. It is surrounded by walls 7 ft thick. This view of the shop interior shows the overhead crane, turntables, and utility pedestals. The latter contains outlets for electricity of various voltages, water, compressed air, and acetylene. Viewing windows are 18 ft above the floor.



OVERHEAD MANIPULATOR and wall-mounted manipulators are seen from the control gallery. The overhead manipulator can lift 500-3000 lb, depending on the arm length and position. All manipulators have a variety of arms to permit many different operations.

Reported by

D. R. Shoults

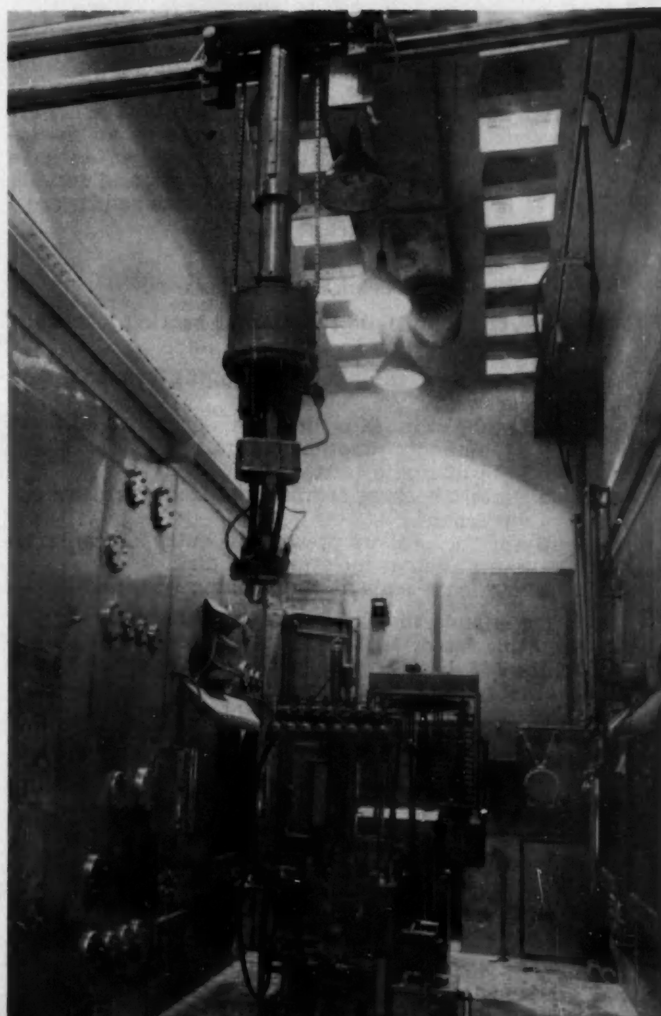
Member, SAE Nuclear Energy Advisory Committee

REMOTE-handling of large mobile nuclear equipment is already being adapted to the servicing of aircraft nuclear powerplants. Work along these lines is proceeding at the National Reactor Testing Station near Idaho Falls, as a part of the AEC and USAF Aircraft Nuclear Powerplant Program.

In the "hot" shop at the Station radioactive powerplants can be remotely disassembled from behind heavy shielding. Remote-handling tools, such as 100-ton cranes and huge manipulators, are required. Operators of these manipulators must be behind heavy walls, yet able to "reach" pieces 50–150 ft away.

Binoculars, telescopes, mirrors, and closed-circuit television help the operator to see at such distances. Three-dimensional color stereotelevision may even become practical to help in depth perception and in "picking out" different colored parts.

Visual aids are largely dependent on the stereoscopic vision of the person operating the remote-handling machines. For this reason a program for selection and development of manipulation technicians has been set up. Included are visual training and exercises several hours a day to improve stereoscopic vision of selected candidates. Six hours of exercise a month are needed to maintain the required stereoscopic visual skill.



THE RADIOACTIVE MATERIALS LABORATORY shown here is on one side of the "hot" shop and connected with it via a remotely operated plug door. In this so-called "hot" cell highly radioactive components can be viewed through windows and periscopes, dissected by metallurgical and machine tools, and examined in a variety of ways, all by remotely operated equipment. The huge manipulator (shown mounted on a crane bridge) will lift 40-750 lb, depending on the position of the hand. Normally, the room is a gadgeteer's paradise—filled with tables on which are placed the tools and apparatus for doing this work; a remotely operated lathe, milling machine, and grinder; also, scissors, specimen-mounted presses, a canning machine, and a balance accurate to a milligram. After completion of examination, radioactive components are literally "canned up," that is, placed in lead pigs for transportation to other locations.

High-temperature bearings

will roll with advances in lubricants, materials, design

Aircraft electric motors are pushing beyond today's bearing temperature and speed performance. Lubrication will play a big role in producing tomorrow's bearings.

BEARING MATERIALS, DESIGN, AND LUBRICATION are keys to aircraft electric motor problems. Temperatures of 600 F+ and −100 F, speeds up to 24,000 rpm, and life in thousands of hours are the goals today—and they are due to go up tomorrow. Lab and field tests are run constantly in a search for better material, lubricants, and designs. In fact, developing tests that give true results are a major problem in themselves.

Lubrication Problems

First, the multiple function of bearing lubricants is to:

- Provide a film between rolling elements and raceways.
- Establish a film between separator surfaces where sliding motion occurs.
- Help dissipate heat.
- Protect bearing components from corrosive environment.
- Aid the seal in preventing entry of contaminants such as moisture and dirt.
- Lubricate seals at the rubbing surface.

Experience to date shows that lubrication is the limiting factor in the life of aircraft motor self-contained bearing applications. Cage breakdown is the typical failure as lubrication becomes inadequate between the cage and the rolling elements.

Second, greases used for lubrication lose their effectiveness through the following processes:

- Oxidation of both oil and grease thickener which is accelerated as operating temperature increases.
- When operating in a vibrational field, the grease tends to slump down into raceways where it is mechanically worked, resulting in breakdown of thickener fibers and excessive "bleeding" of oil from the grease.
- Evaporation.
- Thermal decomposition.
- Lost through the sealing element.

How New Greases Are Developed

Long before a new grease is tried in a bearing application a series of chemical and physical tests are run. The most promising products are screened chemically, in Texaco for example, by checking the viscosity, gravity, flash point, fire point, and pour point of the oil. Fatty materials are evaluated by such tests as neutralization and saponification numbers, (solidification point of the melted fat), and iodine value. The alkalinity and purity of the base are carefully determined so that a proper soap may be formed. In fundamental grease research, the physicist comes to the aid of the chemist with joint studies of grease structure by such tools as the electron microscope and X-ray diffraction studies.

Finished greases are checked for penetration, dropping point, water, free alkali and free fatty acid, and thickener content. Other nonmechanical tests, depending upon the service intended may be bomb oxidation, apparent viscosity, evaporation, and antirust tests. A periodic examination is made of storage stability.

Granting that the physical and chemical properties of a new formula appear in line, the product is then ready for introduction to the mechanical evaluation laboratory to see whether it shows promise as a lubricating grease or is just another unsuccessful colloidal system.

In addition to the mechanical tests shown in Table 1, a new grease may be evaluated by a battery of

Table 1—Mechanical Tests Used to Screen New Greases

Test	Description
1. Torque Breakdown Machine (Ball or Roller Bearing)	A short-time screening test. Measures starting and running torques, leakage, ambient and bearing temperatures under no-load conditions. Common test conditions are 80–250 F for 3 hr.
2. Low-Temperature Torque (to –100 F)	
a. Oscillated Test	Ball bearing periodically revolved clockwise and counter-clockwise during cooling. Time for one revolution taken after a soaking period at the test temperature.
b. Starting and Running Torque Test (MIL-G-3278A)	Ball bearing cooled and soaked without movement, then motor started to give breakaway and running torque (one rpm).
3. Water Resistance	
a. Navy Water Jet Test (ASTM D-1264-53T)	Jet of water impinged on bearing housing with specified clearances, bearing revolving at 600 rpm. Measures grease loss after 1-hr duration.
4. Electric-Motor-Bearing-Type Tests	
a. GE-ASTM[a] Tester (No. 306 bearing, 3500 rpm) 20 hr on, 4 hr off cycle	Simulates moderate-speed service up to 125 C (257 F). Measures performance life and leakage.
b. 10,000-rpm Spindle (Federal Standard 791 Method No. 331), No. 204 bearing; cycle of 22 hr on, 2 hr off	Simulates higher speed, smaller bearing motors and other electrical equipment. Measures performance life from 250 F to 450 F; being extended to 700 F.
c. Silicone-Insulated Motor Generator Set No. 310 bearing, 1750 rpm, 150 hr on, 18 hr off cycle. Two 44 hp motors, one drives the other.	Actual hot-running motor-generator setup with hot bearing controlled at 300 F. Measures performance life.
5. Fretting Corrosion Testers	
a. Fafnir Thrust Bearing Tester (1725 cpm, 500-lb load, 6 deg oscillation, 50 hr)	Measures weight loss of unshielded thrust bearing. No correlation with other bearings in service.
b. Sikorsky Universal Tester—Radial Load, Tests tapered roller, needle, or ball bearings, 5000-lb load per bearing, 6-deg oscillation, 410 cpm.	Measures torque increase with time. Being studied by CRC.
6. SKF Heavily Loaded Tester 5.1-in OD cylindrical roller bearings under 4240 lb radial load and 2100 rpm (cartridge heaters under the test bearings).	Measures endurance life. Usual test is 500 hr, or to failure, at 245 ±6 F and full load.
7. Extreme-Temperature Oscillating Tester 2-in OD control bearing, 200-lb radial load, 90-deg oscillation, 600 cph, 4 hr off, 4 hr on. Performance goal 72,000 oscillations (120 hr) minimum.	Measures time to develop 1 ft-lb torque. Tests run up to 550 F.
8. High-speed Ball Bearing Testers No. 204 (20-mm bore) bearings run at 35,000 rpm.	These testers measure performance life at 35,000 rpm under the conditions shown.
a. Direct motor-driven 80-lb thrust load and 8-hr cycles.	
b. Belt-driven at 20–50-lb thrust load and 35-lb radial load on more continuous basis.	

[a] Proposed.

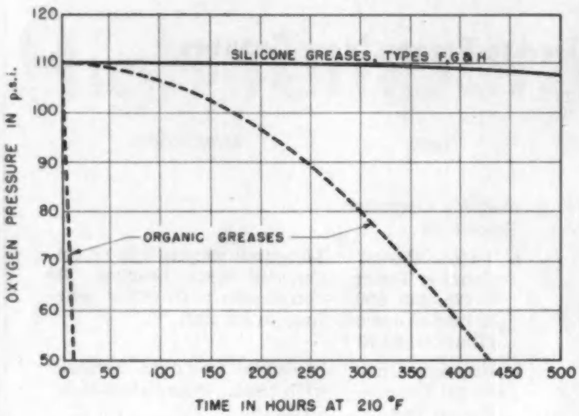


Fig. 1—Silicone greases outstrip organic competitors in oxidation resistance. Both types are held in an oxygen bomb for 500 hr at 210 F with brass present. Drop in oxygen pressure indicates instability.

e-p (extreme-pressure) and wear tests. The 4-Ball E-P, 4-Ball Wear, and Navy Gear Wear Tests are used to rate antifriction aircraft bearing greases. Also, grease performance under a high shear rate (1,000,000 reciprocal seconds) is tested in a rotational viscometer. New developments in high-speed tests show rpm × bore values of 1,000,000 or higher are feasible, using 20-lb thrust loads and 700 F temperatures.

What Lubricates at High Temperatures?

Silicone lubricants took the first high-temperature step over petroleum greases. With a lithium soap thickener the silicone oil outperforms organic oil greases both in life and deterioration. Fig. 1 gives silicone greases a high oxidation resistance rating well into the 350–400 F range. Bearing life is markedly increased in Fig. 2 when silicone grease is used. Typical operative temperature range for these synthetic greases is 350–400 F.

A temperature jump of 50–100 F in performance comes with better thickeners. Aryl-substituted-urea or idanthrene are examples of more stable thickeners used with silicone oil to produce this second temperature step. One drawback with silicone greases is the wear of brushes on d-c motors when silicone vapors are present. There is repeated ex-

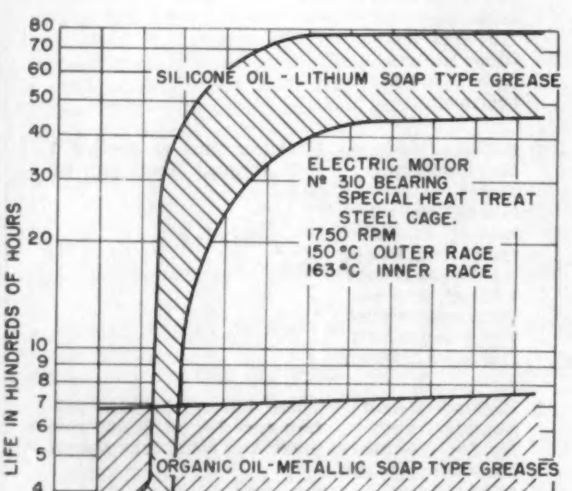


Fig. 2—Bearing life jumps sharply when a silicone grease is used. Only tight shaft fits cut down the performance of the synthetic grease.

Table 2—Lubrication of Steel Surfaces by Powdered Solids in Low Speed (5.7 fpm) Sliding

[Load, 40 lb (three 3/16-in. radius hemispheres on a flat). Atmosphere, dry air unless noted.]

Materials	Typical Friction Coefficient at 75 F	Remarks
MoS_2	0.06	Oxidizes above 750 F
CdI_2	0.06	Absorbs moisture
WS_2	0.08	Oxidizes above 700 F, similar to MoS_2
Ag_2SO_4	0.14	Forms thick, tenacious surface films
Na_2SO_4	0.41[a]	Does not lubricate sliding metals
PbI_2	0.28	Good film formation
Graphite	0.06–0.10 in moist air only)	Will not lubricate in dry air
PbO	0.23	Lubricates well at 1000 F ($f = 0.08$)
BN	0.41[a]	Does not lubricate sliding metals
Teflon	0.06	Excellent lubricant below 550 F
AgI	0.19	Good film formation (not layered lattice)

[a] 0.41 was the limit of the friction indicator in these runs. Actual friction coefficient was higher.

perience that this wear occurs whether the silicone comes from the bearing or perhaps the insulation on a wire.

Solid Lubricants

Above 600 F is in the domain of solid lubricants. Use of these lubricants will probably come in a series of steps. Already resin-bonded solid lubricants have made a dent in tough applications involving temperature and load. Air or liquid-suspended solid lubricants and surface reaction products are other techniques that may become increasingly important.

In picking a solid lubricant, a layer-lattice crystal structure with easy shear planes is preferred. However, Table 2 shows that this does not always give the best coefficient of friction. For example, boron nitride (BN) has the right structure but does not lubricate effectively, while silver sulfate (Ag_2SO_4) is just the reverse. This apparent contradiction can be attributed to the ability of the lubricant to adhere to the surface of the ball or raceway.

Graphite is probably more widely known as a solid lubricant than any other solid material. Its lubricating properties depend on adsorbed vapor films or the presence of proper oxide films on either or both of the lubricated surfaces. Evidence of this is the fact that Inconel can be graphite lubricated at 1000 F and room temperature but not at all intermediate temperatures. The addition of a supplementary oxide allows graphite to lubricate over the entire temperature range even though these data are obtained in dry air. The oxide is believed to promote the adherence of graphite to metals.

One of the drawbacks of solid lubricants is the decreased fatigue life of ball bearings. The solid particles decrease the surface fatigue life of the balls where pure rolling occurs. In sliding areas a uniform layer of solids is formed and individual particles have less tendency to serve as stress raisers.

Control These 6 Problems By Design

Design problems are either inherent to the bearing itself or its surrounding environment. The first three examples are in the former category.

Internal looseness—Cold starts or temperature differentials between the inner and outer race call for stepped up internal radial looseness. While designers hold the looseness down to improve overall accuracy, too tight a fit causes real trouble when a 50 F or greater temperature difference is encountered.

Cage to seal space—Double-sealed or double-shielded bearings leave little space for unchurned grease storage. Less than a 1/32-in. distance between cage and shield should alert the designer to this storage problem.

Race and separator wear—The curvature of the bearing race should be designed to give minimum sliding action or "slip" because a ball is in true rolling motion at only two points on the race. Reducing the raceway curvature helps decrease slip. A practical race curvature limit is 60% greater than the ball diameter. However, load-carrying capacity is reduced with decreased curvature.

Thrust loads cause axial displacement of the inner or outer race. Under these conditions the balls "spin" because the geometry and loads do not permit

THIS article is based on papers and oral discussion presented at a Bearing and Lubrication for Aircraft Electric Motor Applications Symposium.

The oral discussion was reported by **L. A. Zahorsky,** Armament Division, Universal Match Corp., Session Secretary.

The papers were:

"Environmental Factors Affecting Bearings for Aircraft Motor Applications" (Paper No. 17A)
by **Howard B. Johnson,** Westinghouse Electric Corp.

"Mechanical Factors Involved in Bearing Mounting" (Paper No. 17B)
by **Thomas Barish, R. J. Eschborn, and C. M. Ong,** Jack & Heintz, Inc.

"A Method of Evaluating Tolerable Bearing Misalignment" (Paper No. 17C)
by **R. S. Langdon,** General Electric Co.

"Discussion of the Behavior of Bearings Made of High-Temperature Materials (Paper No. 17D)
by **Arthur S. Irwin,** Marlin-Rockwell Corp.

"Effect of Loading Systems and Vibration on Bearing Life" (Paper No. 17E)
by **Carl L. Dellinger,** Norma-Hoffman Bearings Corp.

"Selection and Specification of Antifriction Bearing Greases for High Speeds and High Temperatures" (Paper No. 18A)
by **R. S. Barnett,** Texaco Research Center

"Possibilities in the Field of Dry Lubricants" (Paper No. 18B)
by **Robert L. Johnson,** National Advisory Committee for Aeronautics

"The Characteristics of Silicone Bearing Lubricants" (Paper No. 18C)
by **W. H. Ragborg,** Dow Corning Corp.

"Mechanical Factors Involved in Bearing Design for Aircraft Electric Motors (Paper No. 18D)
by **T. W. Bakewell,** New Departure Division, GMC

To order any of the above papers . . .
. . . on which this article is based turn to page 5.

true rolling motion on one of the races. Low contact angles and open curvatures minimize the spin effect.

Separators must always wear because they have no rolling contact. In fact, the typical bearing failure is a separator failure. Here good lubrication is the main answer, whether by grease or a solid lubricant built into the separator.

Misalignment—All combinations of axial and radial runout of the inner and outer races can cause misalignment. The buildup of tolerances of the motor as well as the bearing are main offenders.

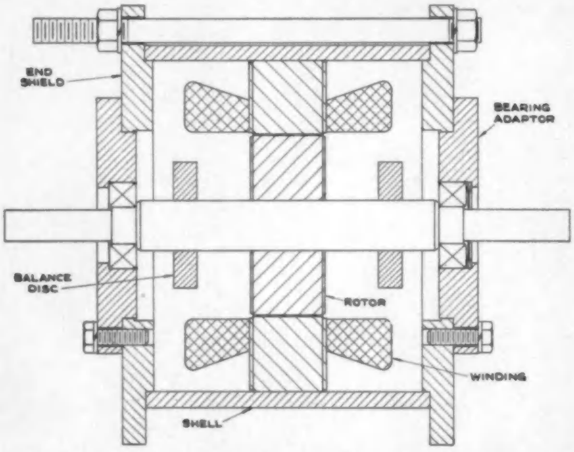


Fig. 3—Bearing outer race misalignment and radial play are deliberately machined into this high-speed test fixture. Armature removal will not disturb stator housing or end plates.

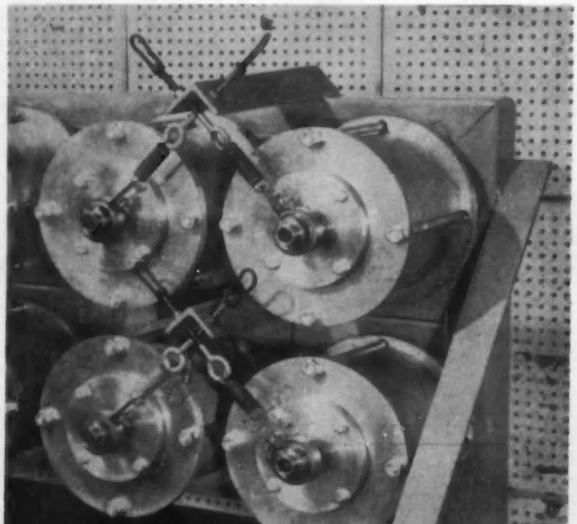


Fig. 4—Bearings undergoing misalignment tests are loaded radially by a tension spring. Axial loading is applied through a Belleville spring inside the housing. All variables except radial play and outer race misalignment are held constant.

The problem is not so much the elimination of misalignment as its control and a knowledge of how it affects bearing life. Life information will come with extensive testing under predetermined misalignment conditions.

A similar problem is "creepage," where the bearings outer race moves out of its housing. A proposed solution is very close tolerances on the bearing OD (ABEC-3 or better), and the housing bore.

Temperature differentials—High differentials require excessive internal looseness. They can be avoided by such design features as hollow shafts, titanium sleeves inside the bearing, heat dissipating collars on the shaft between the bearing and rotor, and increased cooling in the vicinity of the bearing.

Secondary loads—After the design loads are set for a bearing there still remains a series of loadings that are non-intentional. These secondary loads should be eliminated if possible. Alternately, they should be evaluated and allowance made in the bearing selection. They include:

- Gears—Misalignment will produce a load on one section of the bearing. Also, imperfect teeth transmit vibratory loads.
- Armature—Dynamic unbalance and eccentric magnetic forces can produce large vibratory forces. Uneven expansion due to temperature gradients will also load the bearing. High accelerations, especially in light motors with low bearing loads, cause ball "skidding," with resultant wear. This last point leads to an intensional bearing load to prevent skidding.
- External vibration—Vibrations transferred from other parts of the aircraft will aggravate fretting corrosion if the motor is not running. Investigation is still needed to evaluate vibratory effects on rotating bearings. In addition, vibration will break down and cause excessive bleeding of grease.
- External forces—Overall aircraft forces such as gyroscopic couples and linear accelerations also impose loads on motor bearings.

High-Temperatures Push Up Bearing Material Requirements

The old standby, SAE 52100 steel, is left by the wayside around 300–350 F., due to loss of hardness. Life falls off sharply at high temperature and a crevice-type failure replaces the flaking failure which occurrs at room temperature. This is probably due to a corrosive interaction with the lubricant. Even if this steel is used at higher temperatures with light loads it should be stabilized approximately 50 F above expected operating temperature. This is because it is important that austenite be fully converted to martensite. The phase change is accompanied by an increase in volume that will later change the bearing component dimensions.

High carbon chrome steels (440C) will operate effectively in the 400–450 F range. At 700 F an initial hardness of 58 Rc drops to 52 Rc after 10,000 hr. 440C loses its stainless properties at 705 F.

Tool steels such as Halmo an M2 retain their hardness within two points up to 500 or 600 F.

"Stellite," and tungsten and chrome carbides

tested to date show promise of 1000 F+ operation. However, high cost has limited their general use.

Physical Tests Used in Material Selection

Final proof of a bearing is in a field trial. Before this, lab tests have been run on the bearing materials.

Many labs test run bearings in the 35–40-mm bore size range and extrapolate load and speed performance for different sizes. Recently, these tests have been run at elevated as well as room temperatures.

Ball rigs show promise as a screening test of new bearing materials. Rapid accumulation of high load stressing on balls is possible. This rolling fatigue information shows that traditional bending fatigue tests are not accurate criteria for predicting ball fatigue failures.

Standard physical tests, such as tensile strength, yield strength, impact, and hardness form the first methods of material selection.

Misalignment Tests Coming

Special tests are under way to evaluate the effect of bearing misalignment. Information gained will tell how to live with misalignment, since it will always be present in today's manufacturing techniques. G.E. has developed a test rig (Fig. 3) which measures the effect of outer race misalignment and radial play.

Extreme efforts are made to eliminate all other variables and the bearings under test are a special batch with the following specifications:

15 mm—type 77502.
Prelubricated 25% full of Beacon 325 grease (approximately 5 grams) controlled to ±0.005 gram.
Inner race curvature 51.6% of ball diameter ±0.1%.
Outer race curvature 53% of ball diameter ±0.1%.
Ribbon-ear-type steel separators.
ABEC 7 tolerance on bore and O.D. ±0.0001 in. on OD after shielding.
ABEC 7 tolerance on groove parallelism of sides, inner and outer grooves.
Radial clearances of 0.0005 in., 0.0007 in., and 0.0009 in.

The bearings will be run at 22,000 rpm with fixed axial load (applied by Belleville-type springs) and radial load (applied by tension springs shown in Fig. 4). Three values of bearing radial play and outer race misalignment will be tested.

Later, other variables will be included in the program.

Turbocharged Automotive Diesels . . .

. . . operate with less power lag and exhaust smoke when new "aneroid control," which eliminates overfueling, is installed.

Based on paper by

N. M. Reiners and W. D. Schwab

Cummins Engine Co., Inc.

CUMMINS recently released a device called "aneroid control," which, by eliminating overfueling, has proved most helpful in cleaning up exhaust smoke during acceleration of our turbocharged automotive diesels.

At outputs up to 140% of naturally aspirated power, the aneroid control may or may not be necessary to clean up the exhaust smoke.

As the power rating of the turbocharged engine is increased above 140%, the need for aneroid control becomes more and more important. With it we have, for example, been able to eliminate complaints of both power lag and smoke during acceleration. In some of our experimental work, including field testing at much higher power than 140%, the aneroid has actually increased the rate of acceleration of the turbocharger, thereby giving faster power response. It is believed that excessive overfueling during acceleration actually quenches the exhaust, giving lower exhaust gas temperature, which in turn gives less energy to accelerate the turbine.

Actually, the aneroid control device eliminates overfueling during acceleration by modulating the quantity of fuel delivered to the engine cylinders in proportion to the amount of air in the cylinders. To accomplish this, the aneroid is incorporated in the fuel system in such a way that the amount of fuel being delivered to the engine can be varied or modulated automatically in response to the air pressure in the intake manifold of the engine. In other words, since the quantity of air in the cylinders available for combustion is directly related to the intake manifold air pressure, satisfactory combustion during acceleration can be obtained if the quantity of fuel injected is controlled by the intake manifold pressure.

On a turbocharged engine rated at 150% of naturally aspirated power, the aneroid control functions as follows: Upon sudden opening of the throttle from idle to the full-power position, the device limits the quantity of fuel to that which produces approximately 120% of naturally aspirated rated power, and therefore the combustion is good. At 120% naturally aspirated fuel delivery, the air pressure in the intake manifold of the engine is positive and 5 psi under stabilized conditions of operation. In actual practice, the aneroid control automatically begins to turn on additional fuel when the manifold pressure has reached 1 psi. As the turbocharger increases in speed, producing more and more pressure, the aneroid throttle automatically turns on more and more fuel, until full-power fuel delivery is reached, thereby controlling the amount of fuel in-

jected to that which the engine has sufficient air to burn.

If the engine is operating under some partial load and the throttle is suddenly opened to full-power position, something more than 120% of naturally aspirated power would instantly be produced with no lag. For example, if the engine is being operated at a load demand of 100% naturally aspirated fuel, the intake manifold pressure would be approximately 5 psi. At that pressure the aneroid control is automatically in a position which would permit substantially more than 100% naturally aspirated rated power, and therefore, sudden opening of the throttle to the full-power position would instantly produce the higher power. Thus, upon sudden opening of the throttle to full-power position, the aneroid control automatically permits the injection of the maximum amount of fuel that the engine can burn, which is determined by the amount of air in the cylinders available for combustion.

To Order Paper No. 240 . . .
. . . on which this article is based, turn to page 5.

Octane Predictions . . .

. . . of road numbers can be made from Research and Motor Numbers.

Based on paper by

W. E. Morris

E. I. du Pont de Nemours & Co., Inc.

RECENT tests by du Pont engineers point to four conclusions regarding correlations among road octane, laboratory octanes, and hydrocarbon types:

- Modified Uniontown road octane numbers can be predicted fairly accurately from Research and Motor octane numbers.
- Research and Motor octane numbers are about equally important both in today's and tomorrow's cars.
- Because of the relationship between sensitivity and hydrocarbon type, one of the laboratory octane numbers along with hydrocarbon-type data can be used to predict Modified Uniontown road ratings.
- Inclusion of olefin content along with Research and Motor octane numbers makes the prediction of high-speed Modified Borderline rating more accurate; increase in olefin content at given Research and Motor octane numbers tends to decrease the road rating.

In establishing these relationships, three test cars of different makes, for which regular gasoline is recommended, were used to test 48 regular gasolines, to get Modified Uniontown ratings. And three cars of different makes, for which premium gasoline is recommended, were used to test 61 premium and super-premium gasolines.

Then equations predicting Modified Uniontown octane numbers from Research and Motor octane numbers were calculated by multiple regression analysis for each car. Result: Road ratings were predicted within half an octane number of the measured value in two out of every three fuels. (But road ratings are still necessary. Deviations by occasional fuels were appreciable—and of considerable economic importance.)

Multiple regression analyses were also made with the help of an electric computer:

- To determine the effect of hydrocarbon type on Modified Uniontown road octane rating.
- To determine which of nine independent variables have a significant effect on Modified Borderline ratings.

In studying the effect of hydrocarbon type on Modified Uniontown road rating, Research and Motor octane numbers, olefin content, and aromatic content were used as the independent variables. Analysis indicated that Motor octane number contributed little to the accuracy of the prediction. A second analysis was then made with Research octane, olefin content, and aromatic content as variables, resulting in the following equation:

$$\text{Road} = 0.636\ \text{Research} - 0.057\ (\%\ \text{olefins}) - 0.034\ (\%\ \text{aromatics} + 36.7) \qquad (1)$$

Based on Research and Motor octone numbers alone without regard to hydrocarbon type, the following equation was obtained:

$$\text{Road} = 0.839\ (0.5\ \text{Research} + 0.5\ \text{Motor}) + 18.8 \qquad (2)$$

Actually the olefin and aromatic contents do essentially the same job in equation (1) that Motor octane number does in equation (2), but they do it a little better. The root-mean-square errors of prediction are 0.36 for equation (1) and 0.38 for equation (2). For all practical purposes, these errors are equal. Because hydrocarbon type and Motor octane number are doing essentially the same job in both equations, inclusion of one—after the other has been used—does not improve the prediction.

Significance of Variables on MB Ratings

The significance of these nine variables on Modified Borderline ratings was studied: Research octane number, Motor octane number, olefin content, aromatic content, sulfur content, API gravity, 10% point, 50% point, and 90% point.

In arriving at the conclusion that only Research octane number, Motor octane number, and olefin content do have significance, the multiple regression analyses were carried out for 73 high-octane fuel blends in four high compression ratio cars. (Modified Borderline octane ratings were attained at various speeds to show the effect of speed on antiknock quality.)

It was also concluded that the error of predicting high-speed Modified Borderlines is decreased appreciably by inclusion of olefins.

To Order Paper No. 261 . . .
. . . on which this article is based, turn to page 5.

Displacement is key in . . .

Designing for Damage

Shock and vibration problems can be easily handled in the design of products if the engineer works with displacement rather than velocities and accelerations.

Based on paper by

J. T. Muller

Consultant, Convair Division, General Dynamics Corp.

THE design engineer can use "displacement" to find out what will destroy the product he has developed. The ruggedness of the product is as much a part of performance as horsepower is to an engine.

Shock and vibration calculations are most useful if they give the engineer a displacement-time curve on the part being investigated.

A basic system is considered a rigid body, a weightless spring, and a damping device. The latter may be contained in the spring, such as a rubber spring, or on the body, like a dashpot. The system is evaluated by the displacement *between* the body and the base to which the spring is attached. This attack bypasses the confusing situation of accelerations of the mass. The spring is equivalent to the part that fails and the stretching or squeezing of the spring can produce failure.

Useful Design Parameters

Two major parameters can define simple one-degree-of-freedom systems. They are:

- The ratio of peak-body to peak-base displacement (x/a), called amplification factor δ.

- The ratio of input (base) pulse-time interval to the natural frequency of the system (T_o/T). When the base displacement is oscillatory, angular frequencies are used and the ratio is called λ.

The maximum displacement of a simple system is then:

$$x_{\max} = \frac{2\,a\,\lambda}{\lambda^2 - 1} \cos \frac{n\pi}{2\lambda}$$

If the system has $\lambda = 1$, then the maximum displacement is:

$$x_{\max} = \frac{n\pi}{2}\,a$$

where n is the consecutive number of input pulses.

This shows that the displacement of the spring is not large, even at resonance, unless the input pulse is continued through a number of cycles. Examining a similar system with a triangular pulse would again give small displacements. Accelerations for such a system would be enormous and misleading as to the damage being done to the spring.

Critical Damping

Critical damping is defined as interfering with the displacement of a system just enough to prevent the system from oscillating. The damping coefficient then becomes the ratio of the damping present to the critical damping. Table 1 gives a range of damping coefficient, η, along with associated amplification factors.

The relation that establishes amplification factor versus critical damping coefficient at resonance is:

$$\eta = \frac{1}{2}\sqrt{\frac{1}{\delta^2 - 1}}$$

Familiarity with Typical Critical Damping Coefficients Saves the Engineer Time in the Design and Protection of Equipment.

Table 1—Critical Damping Coefficients

System	Critical Damping Coefficient (η)	% of Critical	Amplification Factor
No damping	0	0	
Solid structures	0.01–0.03	1–3	50–15
Complex assemblies	0.07–0.10	7–10	7–5
Synthetic rubber	0.10–0.15	10–15	5–3
Metal mesh	0.15–0.25	15–25	3–2
External damping instruments	0.5–0.7	50–70	1.4–1.2
No oscillation	1.0	100	1.1

To Order Paper No. 198 . . .
. . . on which this article is based, turn to page 5.

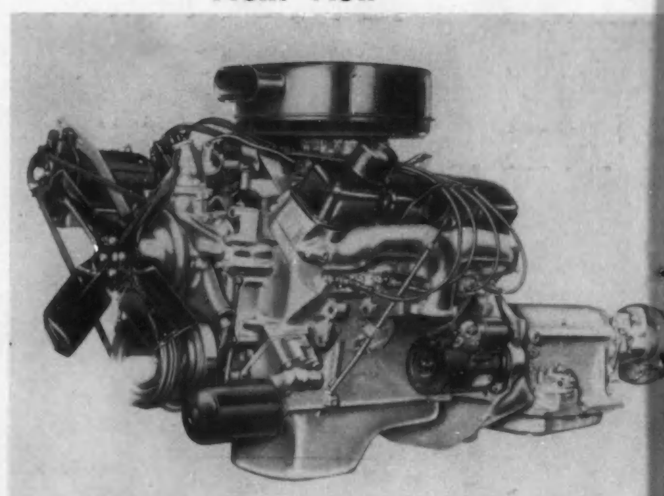
Chrysler's New V-8 Engine

Excerpts from paper by

R. S. Rarey and E. G. Moeller

Chrysler Corp.

Front View



THIS year, Chrysler Corp. has introduced a new V-8 engine, versions of which are available in several models of the Corporation's cars.

For greatest gains in weight reduction, a simpler light-weight head design was incorporated with the conventional wedge-shape combustion chamber with side-by-side intake ports. This gave the desired weight reduction with minimum loss in power potential.

The new head design uses a simplified in-line valve arrangement and features coolant sections in the head without loss of effective cooling. Also, it permits use of the high exhaust manifolds necessary for installation ease. (Large bulky heads and low sweeping exhaust manifolds could not be accommodated in the chassis in which this engine was to be used, without extensive retooling of production frames, steering gears, and linkage.)

The achieved weight decrease is important from a ride balance standpoint. It also improves fuel economy and manufacturing economy. The engine was designed as low as possible to enable a lowering of hoods.

Decision to use this engine in two different wheelbase cars and interchangeably with other Chrysler-built engines without requiring extensive frame, suspension or other component change dictated engine mount position. It also dictated over-all engine height and length, as well as distributor drive and oil pump location. Since any oil pump location extending below the crank throw interfered with the steering linkage of one of the cars, the distributor was moved to the front of the engine and placed on a 45 deg angle parallel to the axis of the right cylinder bank. This made it possible, as seen in Fig. 1, to locate the oil pump which is driven from the distributor drive shaft, on the front of the cylinder block above the lowest point of crank throw. The arrangement relieved any steering linkage interference problems, and also a heater to distributor interference. In addition, it provided a more serviceable distributor location and an easily accessible line-free location for the oil filter which could now be mounted directly on the oil pump cover.

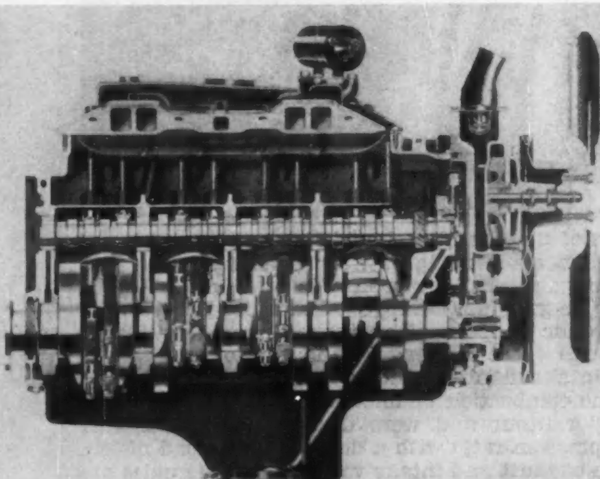
For manufacturing ease, the cylinder head was designed to provide a valve gear arrangement facilitating use of an economical stamped rocker arm mounted on a tubular rocker shaft as shown in Fig. 2. The rocker shaft not only provides a simple and trouble-free bearing for the rocker arms but also serves as an oil gallery to feed all valve gear parts. With this new design, it was possible to omit the conventional drilled cylinder head oil drainback holes in both head and block. Thus, a foundry problem was alleviated and machining operations reduced. These savings were effected by the use of a "pie-shaped" coolant cross section in the head design. Oil from the cylinder head is permitted to return to the tappet chamber by flowing across the nearly horizontal roof of the "pie-shaped" section.

This new engine is a 90 deg V-8 with a bore of either 4 1/16 or 4⅛ in. and a stroke of 3⅜ in. giving piston displacements of 350 and 361 cu in., respectively. The engine features a rigid, deep skirt

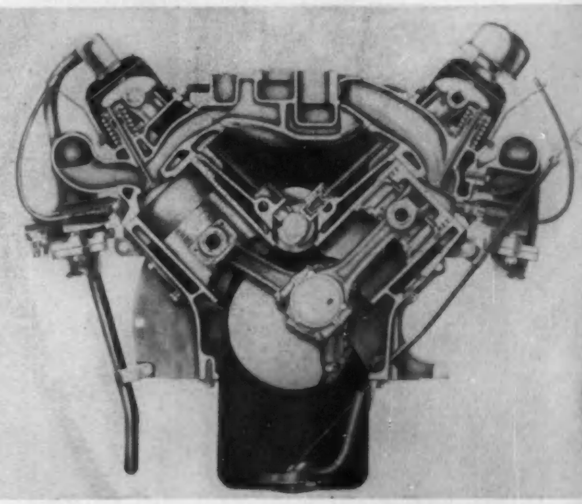
DIMENSIONAL AND WEIGHT COMPARISON

	1957 DE SOTO	1958 DE SOTO
Bore and Stroke — In.	3.78 × 3.80	4.125 × 3.375
Displacement — Cu In.	341	361
Total Weight Including T/C Adapter	674 Lb	638 Lb
Weight per Cubic Inch Displacement	1.98	1.76
Length — Fan to Rear of Block — In.	29.0	32.0
Height — Crank C/L to Carburetor Pad	15.2	13.3
Width — Across Exhaust Manifolds	25.0	26.0

Longitudinal Section



Cross-sectional View



block, in-line overhead valves employing a single rocker shaft for each cylinder head, and wedge-shaped combustion chambers. The compression ratio is 10:1 and engine calibrations are adjusted for operation on premium grade fuel. The dry weight of the engine is 638 lb and its coolant capacity is 10 qt with 6 qt additional in the radiator and hoses.

Cylinder Block

The cylinder block, of gray cast iron, is of a rigid deep-skirt design (Fig. 3), its sides extending downward three inches below the crankshaft center line. The cylinders are on 4.80 in. centers and have .96 in. offset between banks. While increasing the rigidity of the block itself, the deep skirt is primarily designed to improve the stiffness of the whole power plant. The deeper skirt directly supports more of the torque converter housing, or clutch housing, so that the housing and block in combination are less apt to deflect under engine loads. Cylinder block-to-torque-converter housing adapter plates are eliminated.

Cylinder Head

The new compact design of the chrome-alloy cast iron cylinder head features minimum bulk and exceptionally short, direct exhaust passages, offering virtually no obstruction to the flow of hot gases. Water-jacketing of the adjacent common-walled intake ports is greatly reduced, although careful attention has been given to the cooling of the valve seats, valve guides, and combustion chambers (Fig. 4.)

An air jacket around the exhaust crossover passage in the cylinder head, which is vented to the atmosphere, prevents overheating of the intake side of the head and prevents oil from contacting the exhaust crossover. The underside of the exhaust crossover is shielded by a projection of the cylinder head gasket.

Numerous benefits accrue from the new head design. The extremely short exhaust ports reduce heat rejection to the cooling system. The smaller

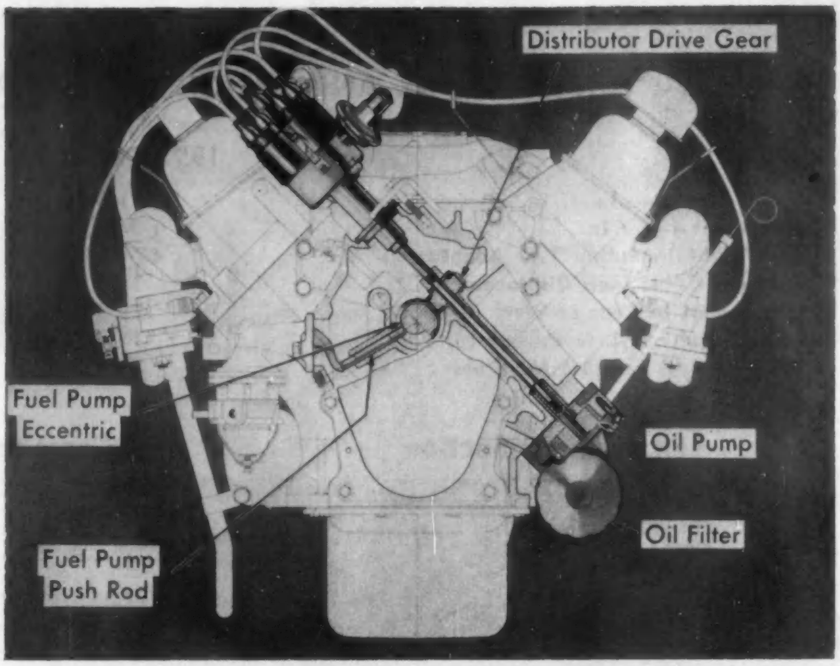


Fig. 1—Distributor, Oil Pump and Fuel Pump Drive.

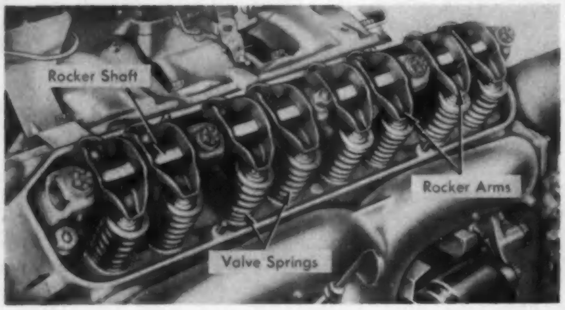


Fig. 2—Rocker Arms and Valve Train.

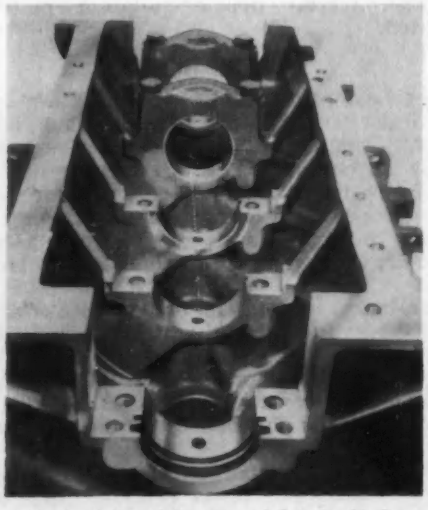


Fig. 3—Bulkhead Structure of Cylinder Block.

mass of metal and coolant heats more rapidly and provides quicker engine warm-up. The large cast openings around the push rods provide drain-back of valve gear lubricating oil, and accessibility to the hydraulic tappets. The tappets can be replaced through these openings without prior removal of the intake manifold and tappet chamber cover.

The combustion chambers (Fig. 5) have an "as-cast" contour and were designed to obtain 10:1 compression ratio with a desirable flat head piston. Both exhaust and intake valve seats and guides are integral with the cylinder head. The horizontally-positioned spark plugs are located at the wide end of the wedge-shaped combustion chambers. The valves are of generous size with valve head diameters being 1.95 in. for the intake and 1.60 in. for the exhaust both having ⅜ in. diameter stems.

For less distortion and improved sealing, the number of cylinder-head bolts is increased from 10 to 17 in each head, so placed that five bolts are spaced symmetrically around each cylinder. This attachment of the cylinder heads provides better sealing, in conjunction with a .015 in. thick embossed steel gasket.

Cylinder Head Covers

The cylinder head covers are attached to the cylinder heads by means of four screws along the gasket channel. A coated cork gasket is used to seal between the cylinder head covers and the as-cast gasket rail on the top of the cylinder head. Provision is made in these covers for crankcase ventilation and the addition of engine oil.

Crankshaft

The forged-steel crankshaft is extremely stiff, minimizing engine noises originating from crankshaft vibrations. The stiffness is the result of hav-

ing large journals, 2⅝ in. mains and 2⅜ in. rods, and a short 3⅜ in. stroke which provides 13/16 in. of crankshaft journal overlap. The crankshaft is 27 in. long and the torsional natural frequency is 333 cycles per second. This rigid design results in lower imposed stresses, particularly in fillet areas. A new high-speed turning process provides very smooth fillets of controlled shape which greatly increase crankshaft strength. Axial crankshaft thrust is taken on the flanged #3 main bearing.

The large crankshaft journals are supported by five babbitt-on-steel main bearings. While the upper bearing shells have conventional oil holes and grooves, the grooves have been eliminated from the lower shells to increase their load-carrying ability. The resulting increase in the main bearing area is approximately 10% but the effect due to the more advantageous L/D ratio is much greater.

A torsional-vibration damper is mounted on the front end of the crankshaft.

The new engine is dynamically balanced during assembly to ensure vibration-free operation.

Connecting Rods

The short connecting rods of alloy steel designed on 6.36 in. centers are forged to a tapered I-beam section which combines maximum strength with minimum weight. The rods are conventional except for the use of piston pins which are pressed into the small ends with an interference fit of .0007/.0012 in. This eliminatees the need for a bushing in the rod and for lock rings in the piston. The rod bearings are babbitt on steel with a projected area of 2.23 sq in.

Pistons and Rings

The cam-ground, aluminum-alloy pistons incorporate a steel strut for expansion control of the piston skirts. Two 5/64 in. wide compression and one 3/16 in. wide oil-control rings all located above the pin, are used on each piston. Compression rings and pistons are tin-coated to prevent scuffing during break-in. The oil ring is a conventional cast iron type, spring loaded by a hump type expander spring which is burred to keep the ring from rotating.

The 1.09 in. diameter piston pin is offset 1/16 in. from the piston center line towards the thrust face and has a clearance of .00045/.00075 in. in the piston bosses.

Camshaft

The hardened cast iron camshaft is located in the conventional position and is driven through a ½ in. pitch and ⅞ in. wide timing chain and sprockets from the crankshaft. The compact arrangement of this drive is shown in Fig. 6.

It has an integral oil pump and distributor drive gear and fuel pump eccentric. The five replaceable bearings are babbitt on steel. Rearward camshaft thrust is taken by the rear face of the cast iron camshaft sprocket bearing directly on the front of the cylinder block, thus eliminating the need for a separate thrust plate. The camshaft lobes and fuel pump eccentric are hardened to 48 Rc minimum.

Tappets, Rocker Arms, and Valves

The overhead valves, operating at a 30-deg angle from the vertical, are actuated from the camshaft through a conventional train consisting of hydraulic tappets, 5/16 in. diameter solid push rods, and stamped steel rocker arms.

Integral-type hydraulic tappets having a spring-loaded flat check valve maintain zero clearance throughout the valve mechanism by means of a column of oil supplied from the engine lubrication system.

One-piece stamped-steel rocker arms, oscillating on tubular steel shafts, transmit valve train motion from the push rods to the valve stems with a 1.5:1 valve-to-cam motion ratio. The rocker arms are separated on the rocker shaft by means of Oilite spacers rather than by springs, as in previous de-

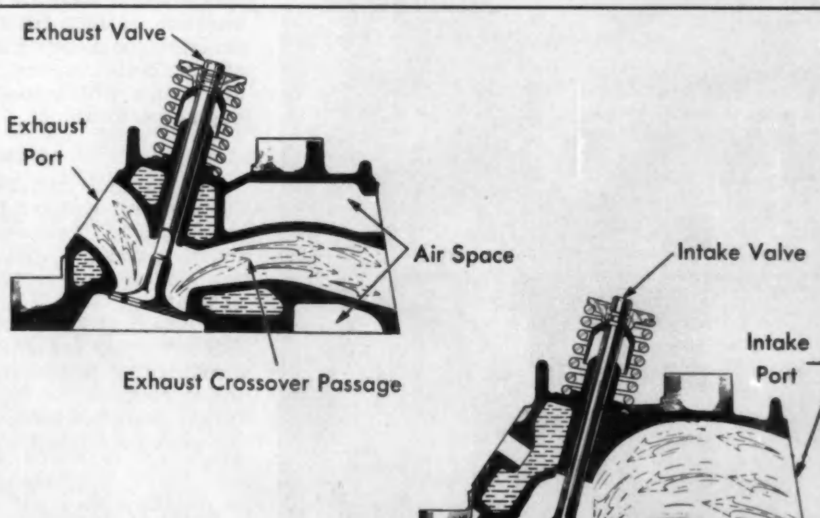


Fig. 4—Cylinder Head Section through Valves.

signs, because push rod angularity tends to force the pairs of rocker arms together, rather than apart. Small die-cast aluminum brackets attack each rocker shaft to the cylinder head.

The rocker arm, which bears only on the lower half of the shaft is made from a single piece metal stamping. It is wide enough to permit forming the rocker shaft holes from the inside, thus facilitating the stamping operations and alleviating the possibility of any burrs on the shaft bearing surface. The bearing surface is coined to provide a uniform contact between shaft and rocker arm. A lubrication groove 90 deg to the shaft axis is formed at the same time the rocker arm shaft bearing surface is coined. Push rod lubrication is accomplished by feeding oil from a hole in the rocker shaft, through the coined oil groove in the rocker arm bearing to a small punched hole at the base of the concave 5/16 in. diameter spherical push rod seat.

As the rocker arm is placed in the engine, it would appear that the lubrication of the push rod socket has been attained by making oil flow up hill. Actually this has been accomplished by damming the oil against the rocker shaft to a point where the oil level reaches the punched hole for lubricating the push rod as shown in Fig. 7. The valve end of the rocker arm is lubricated by gravity flow since the valve tip is lower than the rocker shaft oil supply.

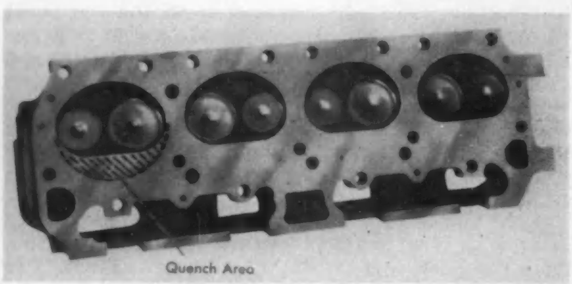


Fig. 5—Cylinder Head Showing Combustion Chambers.

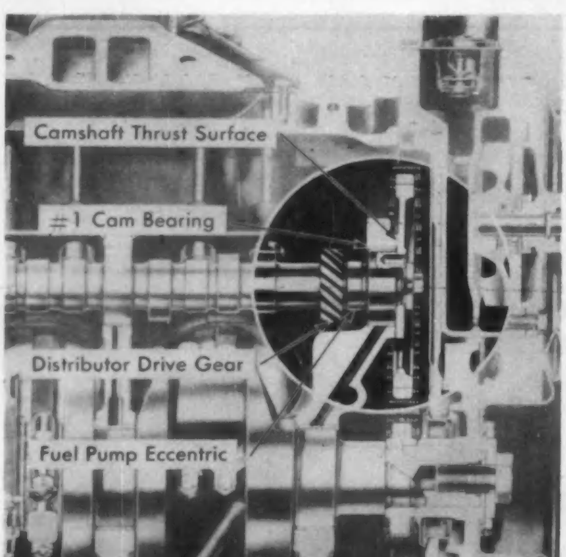


Fig. 6—Longitudinal View of Distributor Drive.

Since valve life is limited primarily by the ability of the metal to withstand heat, both intake and exhaust valves are made of special heat-resistant, high-alloy steels—silicon-chromium (8440) for intake valves, nickel-manganese-chromium (21-4N) for the exhaust valves. Further protection from high and non-uniform temperatures is provided by the ample supply of coolant supplied by the new series-flow cooling system.

Both intake and exhaust valves are "tulip" shaped. This provides greater flexibility and therefore better seating of the valves. It also reduces the weight of the valves, lowering their inertia and enabling them to be operated at high speeds by valve springs of moderate load which do not impose excessive loads on the cams and tappets.

Although no valve rotators are employed as such, the normal slight vibration of the valve train and springs is sufficient to overcome the low resisting torque of the valves and cause them to rotate, even at relatively low engine speeds.

Intake Manifold

A very compact and light intake manifolu (Fig. 8) is used in conjunction with a separate tappet chamber cover.

For intake mixture heating, a crossover in the intake manifold conducts exhaust gases from the No. 4 exhaust port in the right cylinder bank to the hot spot, and out through the No. 5 exhaust port in the left bank.

A constant cross sectional area of 2.0 sq in. is maintained in the intake system from the base of the carburetor risers to the intake valve seats. This has been found to be the best compromise for engine output and driveability over the speed range. Furthermore, there is no sump in the fuel-air passages between the carburetor and the valve seats thereby avoiding "flash" and "puddling" problems.

The intake manifold has a low silhouette which, in combination with the lower engine and shorter carburetors, permits adoption of the more efficient concentric-type, paper-element air cleaners. The concentric design makes possible better air-flow characteristics which in turn contribute to improved engine performance.

Exhaust Manifolds

The exhaust manifolds are located on the outer sides of the cylinder heads, immediately above the spark plugs. Their new, separated-branch design makes gaskets unnecessary because the branches are flexible enough to absorb the distorting effects of heat.

A shield at the heat-control valve on the right-side manifold prevents cold air from the fan from stroking the temperature-sensitive bi-metal spring which controls the valve. This aids in maintaining intake manifold temperatures at the optimum level for peak performance and maximum fuel economy.

Cooling System

Uniform metal temperatures are maintained throughout the new engine because of the careful attention given to the design of the cooling system

and its new series flow pattern. (Series flow means that all of the coolant in each cylinder bank is forced to pass first around all of the cylinders and then, in its return through the cylinder head, around all of the valve seats.)

The high-capacity centrifugal water pump is bolted to the front of the engine and belt-driven from the crankshaft pulley. Coolant from the radiator enters the pump from the lower left side and is directed to the front of both cylinder banks by a symmetrical scroll in the pump housing (Fig. 9). The coolant then flows around the cylinders to the rear of the block, and upward through matching holes in the block and cylinder head.

Virtually all of the coolant circulating in each bank passes through these holes of about one square-inch area at the rear of each bank. The flow is then from the rear of the cylinder heads, past all of the valves and seats in each cylinder bank, into passages in the forward end of each bank of the cylinder block and thence into a common manifold which is an integral part of the water pump housing. The coolant then passes through a thermostat and into the radiator top tank.

A permanent by-pass in the water pump housing, between the engine discharge and the pump intake, maintains circulation through the engine during warm-up. The high point of the cooling system (See Fig. 9) is at the cylinder block water outlet. This is desirable for proper elimination of air or vapor from the cooling system during filling and engine operation.

With a wide open thermostat and at 2,000 engine rpm, the coolant flow is approximately 300 lb per minute. At wide open throttle, the coolant temperature rise through the engine is 7–9 deg over the speed range. The heat rejection per bhp at wide open throttle varies from 31 Btu per minute at 2000 rpm to 28 at 4000 rpm.

The over-all coolant capacity of the engine cooling system including the radiator is 16 qt. This is appreciably less than other V-8 engines of comparable displacement. A large part of this reduction is made in the cylinder heads as each head of the new engine contains only 1.2 qt.

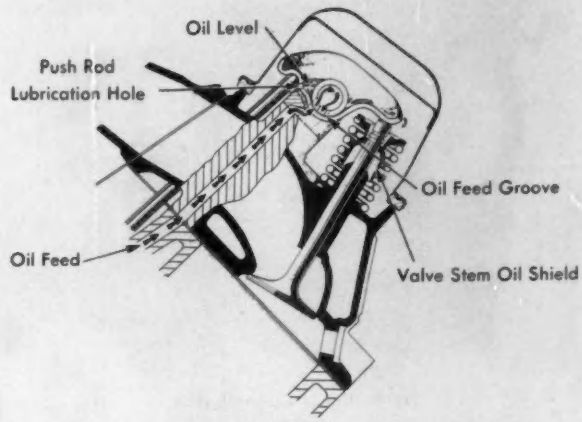


Fig. 7—Cylinder Head Valve Mechanism Lubrication.

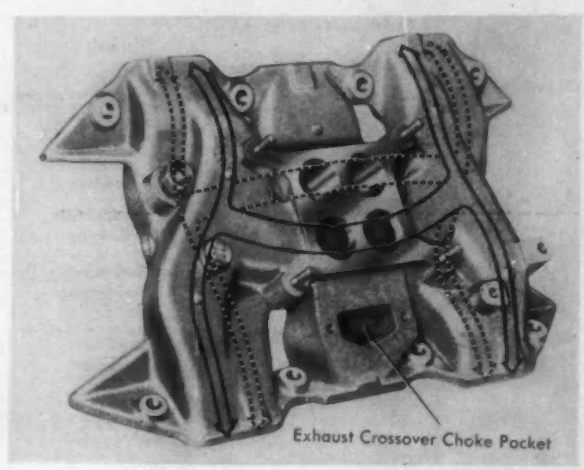


Fig. 8—Intake Manifold (4-Barrel Carburetor).

Lubrication System

The lubrication system consists of an oil sump in the pan, a rotor type oil pump, full-flow filter, and a series of passages to deliver the oil as explained below (Fig. 10).

The oil pump draws the oil from the sump through a fixed screen suction pipe and forces it through the full-flow filter. From the filter, the oil moves across the front of the block through a drilled passage to the right oil gallery. The passage that carries the oil to the right gallery is intersected by holes which feed the No. 1 main bearing and the No. 1 camshaft bearing. The right oil gallery supplies the other mains and the camshaft bearings through drilled holes. The rod bearings are lubricated through holes drilled in the crankshaft to the nearest main journal.

Squirt holes in the connecting rods spray oil on the cylinder walls.

The piston pins are lubricated by splash oil which drains down from the underside of the piston heads through holes in the piston pin bosses. Intersecting holes through No. 4 camshaft journal meter oil to drilled holes in each bank which carry it up through the cylinder block and heads to the rocker shafts. Holes in the rocker shafts oil the rocker arms. A crossover of the rear of the block transfers oil from the right gallery to the left. The tappet bores for both cylinder banks intersect the oil galleries so that oil is fed directly from the galleries to the hydraulic tappets. The gerotor type oil pump is mounted externally on the lower left-hand side of the block near the front. It is driven through a hexagonal joint by the oil pump and distributor drive shaft.

The replaceable can type filter contains an integral anti-drain back flapper type check valve and a relief valve which opens to supply oil to the engine if the filter becomes clogged. The filter can be replaced by hand without the use of wrenches from the underside of the car.

Engine crankcase ventilation is by road draft tube connected to the right cylinder head cover with the fresh air entering at the oil fill cap on the left cylinder head cover. A baffle is installed in both

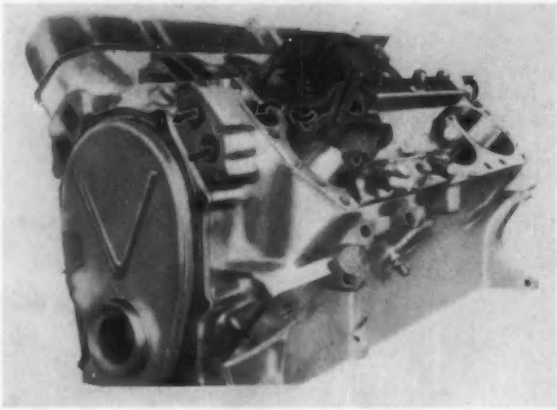


Fig. 9—Engine Cooling System.

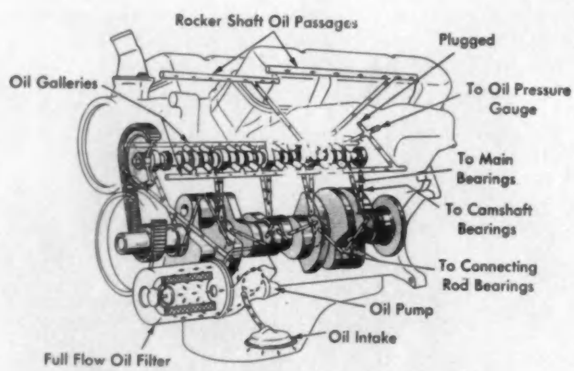


Fig. 10—Engine Lubrication System.

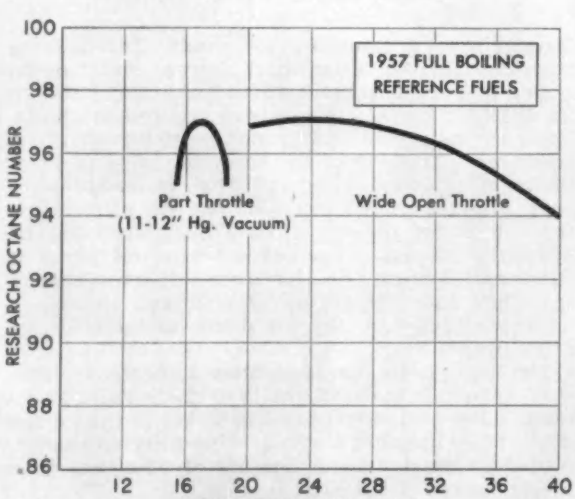


Fig. 11—Road Octane Requirement.

cylinder head covers below these openings to prevent oil loss.

Generator, Starter, Battery

The 12-volt, 30-amp generator is mounted above the front of the right bank exhaust manifold, on a bracket attached to the manifold extension.

The torque output of the starter motor has been increased to ensure adequate cranking speed of the larger displacement, higher compression engine. As compression ratios increase, hot cranking of engines requires more power due to auto-ignition and resulting higher cylinder pressures. Fuel, cranking speed, and engine temperatures are important variables in this problem.

Capacity of the battery is increased 20% (to 60-amp-hr) to compensate for the higher cranking load imposed by the new engine.

Carburetors

Both the 350 and 361-cubic inch engines have models which use Ball and Ball (BBD) dual carburetors and Carter AFB four-barrel carburetors.

In designing the carburetor, specific attention was given to obtaining a low over-all height of 3.96 in. as compared to 4.53 in. on other Chrysler Corp. dual carburetors. To promote air cleaner interchangeability, the same 4.18 in.-diameter air cleaner mounting pilot was incorporated as is used on the four-barrel carburetors.

The bowl capacity of this carburetor was designed to have 90 cc of usable fuel as compared with 47 cc on the previous dual carburetors.

During hot weather testing, it was found desirable to incorporate an outside bowl vent which is opened when the throttle is closed for idle. The outside vent is open only at idle to maintain complete internal balance under conditions of higher air flow when air cleaner restriction would influence carburetor metering. To reduce the heat transfer to the bowl, a 1/8 in.-thick insulating gasket is used between the throttle flange and the main carburetor body containing the bowl.

The carburetor was designed to allow all castings to be made of aluminum for reduced cost.

A distinctive choke system is used for both the dual and four-barrel carburetors. The bimetallic choke coil is located in a pocket in the exhaust crossover passage of the intake manfold. A rod connects the choke coil unit to the choke shaft in the carburetor air horn.

To obtain choke mixtures more nearly matching engine requirements, a staged vacuum piston is incorporated in the air horns of the dual and four-barrel carburetors. It has a finer degree of control to obtain the correct choke blade relationship between wide open throttle and part throttle during the entire warm-up cycle.

During the first five miles of a start and warm-up cycle, substantial fuel economy gains resulted from the use of this staged piston.

Fuel Pumps

A mechanically-operated diaphragm-type fuel pump selected for good vapor lock performance is used. To promote good fuel and vapor handling performance, two inlet and one outlet valves are used. The pump is driven by a camshaft actuated

push rod contacting the pump lever arm (See Fig. 1). The pump is mounted on the right side of the block near the front.

Engine Weight and Physical Size

The over-all dry weight of the new engine as used in the 1958 De Soto is 638 lb including starter, generator, front engine supports, air cleaner, carburetor, distributor, vent pipe, spark plugs and wires, pulleys, and belts. The weight is complete from the fan to the crankshaft flange except for special accessories, such as the power steering pump and belt drive. This weight is for an engine which still has some space for future displacement increase. Comparison with the '57 De Soto engine is made at the beginning of this article.

The fuel octane requirement data from production-built engines and using commercial reference fuels are shown in Fig. 11. Most of the engines used in this evaluation have less than 3,000 miles of deposit accumulation.

Tests have shown also that part-throttle knock is affected much more than wide-open-throttle knock by high engine air and coolant temperatures (approximately one octane number increase per 10-deg increase in coolant temperature). This problem is becoming more apparent as compression ratios increase and is not a peculiar characteristic of this particular engine.

To Order Paper No. 32B . . .
. . . on which this article is based, turn to page 5.

Time and Fuel

. . . required to fly the DC-8 between two airports is being figured on digital computers for scores of route segments.

DOUGLAS AIRCRAFT COMPANY, INC.

ROUTE ANALYSIS

MODEL	ROUTE	DISTANCE	OP. WT. EMPTY	RES. FUEL	WIND	SPEED	JOB
DC-8	LAX TO CHI	1,521 N. MI	123,656 LB.	15,000 LB.	ZERO	KTS	57-53

BLOCK TIME (HR.)	CENTS PER 200 LB. MI.	INITIAL ALT. FINAL ALT. (FT.)	WIND	CRUISE POWER SETTING INITIAL	FINAL	TAKE OFF WT LANDING WT. (LB.)	PAYLOAD BLOCK FUEL (LB.)	V BLK. V CR.	$ PER TRIP $ PER MILE
3.27	1.451	25,000	0		85NRT	232,399 169,056	30,400 63,343	466 516	3,354.78 2.21
3.32	1.403	25,000	0		M.84	225,963 169,056	30,400 56,907	458 505	3,243.80 2.13
3.35	1.340	30,000	0		M.85	218,659 169,056	30,400 49,603	454 501	3,098.75 2.04

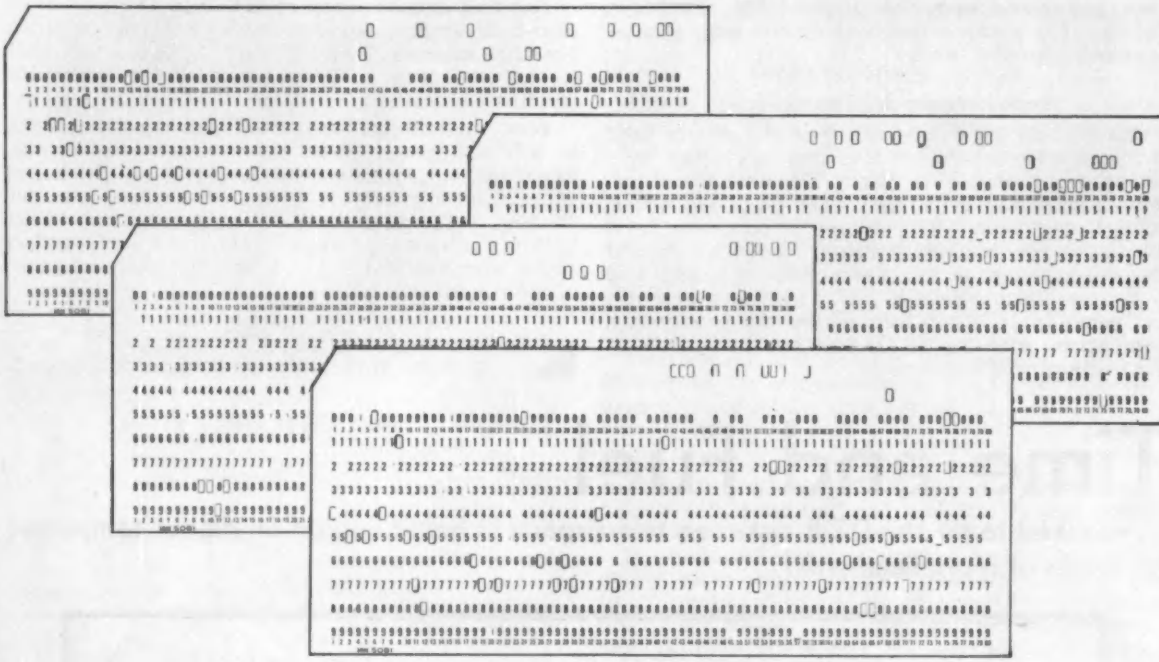
Based on paper by
A. C. Butterworth and G. E. Hull,
Douglas Aircraft Co., Inc.

DOUGLAS is performing such studies for the future operators of the new jet transport, as illustrated by this Los Angeles to Chicago flight analysis.

Beneath the heading is a series of solutions, each for a different flight procedure. The first block relates to a flight at 25,000 ft with a cruising power of 85% normal rated thrust, under conditions of zero wind.

In this instance, the block time is 3.27 hr and the cost in cents per 200-lb-mile (nautical) is 1.451. Other columns give the take-off weight with the landing weight printed below, the payload in pounds, the block fuel, block speed, cruise speed, dollars per trip and dollars per mile. The analyst selects from this list of possible solutions which are sorted by computer in order of block time. If required, the computer will print only the five fastest and five cheapest methods.

To Order Paper No. 193 . . .
. . . on which this article is based, turn to page 5.



Digital Computer Simulates Free-Piston Engine

Excerpts from paper by **Donald R. Olson** General Motors Research Staff

THE analytical simulation of a free-piston engine shows promise in the investigation of many facets of engine operation. It appears to be sufficiently realistic so that the merit of major changes in engine design and operating conditions can be easily evaluated. It is obviously a relatively cheap tool compared to the construction and test of operating units.

However, it cannot be looked upon as a substitute for engine development. Many important aspects of the processes which occur in the engine and greatly influence the performance still defy analytical treatments. The simulation can be considered as a valuable adjunct to engine development. In particular, it can be used to gain a better understanding of the many parameters that influence operating units.

The Engine

The design of the engine treated in this analysis is termed an "inward compression machine." Fig.

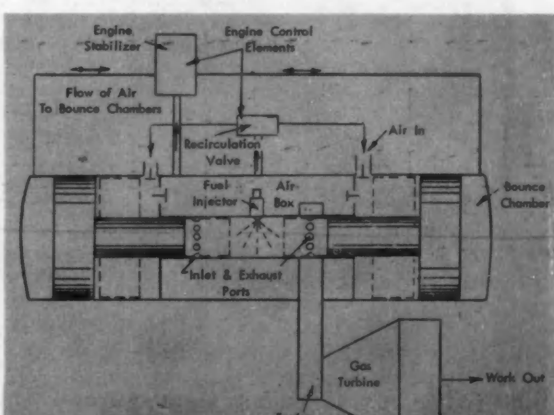


Fig. 1—Free-piston engine-gas turbine combination.

1 shows the basic configuration. The engine operates with a back pressure of considerable magnitude and it produces work only in the sense that it supplies high-pressure combustion products to operate the gas turbine.

Atmospheric air is inducted into the two air compressor cylinders on the outward stroke of the two pistons (the motion of the pistons is synchronized). The air is then compressed during the inward stroke and discharged into the air box. As the pistons are pushed outward by the high-pressure gases in the combustion chamber, the exhaust ports are uncovered first and a portion of the combustion products flow into the exhaust collector.

The inlet air ports are uncovered next and air flows from the air box into the combustion cylinder where it serves to scavenge the remaining combustion products from the cylinder through the exhaust ports. As the pistons move inward again both the inlet air and exhaust ports are covered and fresh air is trapped in the combustion chamber for the succeeding diesel combustion process. Air trapped in the bounce chambers serves to keep the two pistons in motion.

As the engine-turbine combination is operated over the load range the turbine inlet pressure (engine exhaust pressure) must change from a maximum value at full load down to nearly zero for idling conditions. This is accomplished primarily by controlling the quantity of fuel injected into the combustion chamber.

Additional control is needed, however. It is provided in two ways. First, the mean pressure in the bounce chambers is controlled so that the piston motion tends to remain within the operable limits. As the fuel rate is increased, the outer limit of piston motion (outer deadpoint, odp) moves outward. To keep the stroke within limits, additional air is then admitted to the bounce chambers from the air box. For low fuel flow rates the opposite effect must be achieved; air is released from the bounce chambers to ensure that piston motion is greater than the operable minimum, that is, the engine will stall if the ports are not sufficiently uncovered.

This control of the bounce chamber air is accomplished by the engine stabilizer. It is actuated by the pressure in the air box which is directly related to the engine back pressure for most engine operating conditions. Second, the gas flow rate produced by the engine, at low engine back pressures must be drastically reduced to match the flow characteristics of the turbine. This may be accomplished either by restricting the flow of air into the air compressors (throttling) or by recirculating a portion of the compressed air from the air box back to the intake of the compressors.

Engine Processes

During each cycle of piston motion several processes occur simultaneously within the engine. They may be described as follows:

Bounce Chamber

The air trapped in the bounce chambers is simply compressed and then expanded as the pistons move through a cycle of motion. The process can be represented on pressure-stroke coordinates as shown

the free-piston engine . . .

has pistons that oscillate without direct mechanical control. In this way the pistons transfer energy between the several processes that occur simultaneously in the engine.

The forces which act on the free pistons to produce the oscillating motion are mainly due to gas pressures characteristic of the processes occurring in the engine. If the basic engine dimensions are not compatible, the gas pressures produce a piston motion that exceeds the limits of operation.

In addition, the engine is normally started during a single initial stroke under conditions far different from those used in normal operation. The engine dimensions must also be correct for this starting process.

For these reasons, a thermodynamic study of piston motion is needed to determine the more desirable basic engine dimensions. For the design and study of a particular engine, however, a more complete analysis must be made. Each process must be studied with respect to the functioning of the engine and the thermodynamic analysis must be augmented with a dynamic study of piston motion.

The purpose of the research described in this article was to formulate a general analysis of the free-piston engine process which would realistically simulate an operating engine.

The analysis was made in terms of variables which first, allows the basic engine size and configuration to be selected and second, allows the operating conditions for the hypothesized engine to be arbitrarily fixed. For these conditions, a solution from the analysis gives a numerical description of the performance that may be expected of the engine.

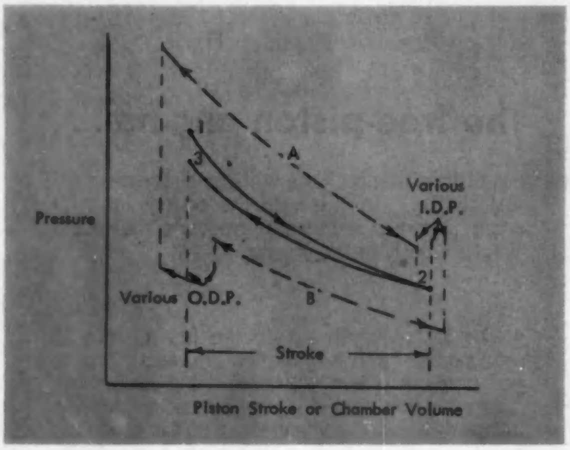


Fig. 2—Bounce chamber process.

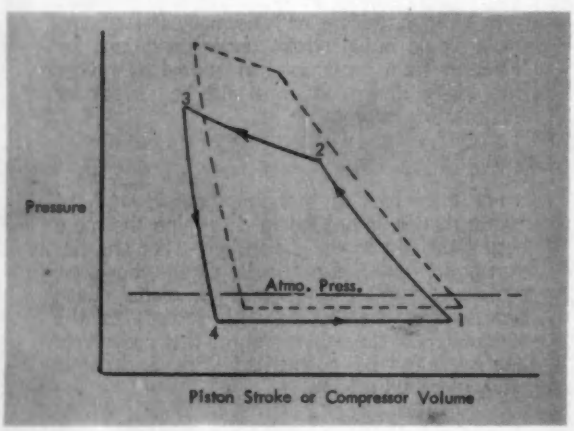


Fig. 3—Air compressor process.

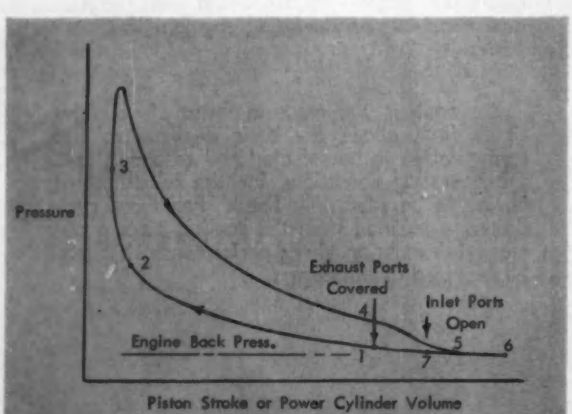


Fig. 4—Power cylinder process.

by the solid curves in Fig. 2. If the compression and expansion occurs without leakage and subject to reversible heat transfer processes, then the processes *1-2* and *2-3* would be superimposed. For other engine operating conditions the path of the process can be substantially changed.

The path *A*, for instance, would represent the situation when the engine was operated with a higher bounce chamber pressure. Additional air has been admitted to the bounce chamber to increase the mean pressure and the piston stroke has been increased. Also, the innermost point of piston travel (inner deadpoint, idp) would change, which produces a piston motion over a different portion of the cylinder.

Path *B* represents the opposite effect.

Air Compressor

The air inducted into the engine is compressed and then delivered into the air box. The compressor section of the engine operates in a manner similar to an orthodox piston-type compressor but with important differences. For a given operating condition the pressure-stroke history in the air compressor for one cycle of piston motion may be represented as shown by the solid curves in Fig. 3.

Process *1–2* represents a simple compression process Delivery of air into the air box begins at point *2* and this pressure is variable depending upon the engine back pressure. The pressure increases during delivery (process *2-3*) because the volume of the air box is relatively small and no air escapes from the air box during the delivery process. Process *3-4* represents a simple expansion process for the clearance air in the compressor and the induction process is represented by *4-1*.

Once again for other engine operating conditions this picture of the compression process may be considerably altered. If the engine back pressure is increased, the odp increases and the compression process begins earlier. The pressure when delivery begins changes and the idp also changes. (See dashed curves, Fig. 3). A reduced engine back pressure produces other similar changes. If the inlet air is throttled, then the pressure during the induction process is lowered.

Power Cylinder

The processes which occur in the power cylinder are similar to those of a two-stroke diesel engine but subject once again to important differences. The solid curves (Fig. 4) represent the pressure-stroke history for a given operating condition.

Fresh air is trapped in the cylinder upon the covering of the exhaust ports (point *1*). As the pistons move inward the air is compressed (process *1-2*). At point *2* fuel begins to flow from the injection nozzle and injection continues for some period of time (points *2-3*). The ensuing combustion combined with further piston motion causes the pressure to rise. Finally the pistons stop (idp) and as the pistons move outward the combustion process continues as the products of combustion expand. Upon the uncovering of the exhaust ports, the combustion products flow into the exhaust collector (points *4-5*). As the inlet air ports are uncovered air flows through the power cylinder from the air box scavenging the

cylinder. Scavenging can continue as the pistons move to odp and back to the point where the inlet air ports are again covered (points 5-6-7).

As in the previous cases, this picture of the processes in the power cylinder changes radically for other engine operation conditions.

The Analysis

The motion of the engine pistons serves as a useful focal point in the examination of engine operation. The energy exchange between the three basic engine processes described occurs as a result of piston motion. The quantity of air delivered by the air compressor is directly influenced by the piston motion. In fact, it is found that all of the desired performance results may be computed directly from the piston motion-time history.

One of the pistons may be considered as a mass upon which a variety of forces act. If these forces at any particular piston position are not completely in equilibrium the piston will accelerate.

The forces considered in this analysis, mainly the result of gas pressures, are indicated in Fig. 5. For the purpose of analysis it is only necessary to consider a single piston in conjunction with the half of the engine in which it operates. The forces F_1, F_2, and F_3 represent the forces acting on the piston in the bounce chamber, air compressor, and power cylinder respectively. The forces F_4 and F_5 represent friction effects that depend upon the direction of piston motion. The position of the piston is measured with respect to the fixed x axis shown in Fig. 5. x is chosen as zero when the piston is near the outer limit of travel and increases as the piston moves inward.

The basic dimensions of the engine may now be notated. The notation refers to a given piston position, that is, $x = 0$. The design of the engine for the analysis may be completely stated in terms of eight design parameters. They are defined as follows and are indicated in Fig. 5.

Design Parameters

- a—Size of bounce chamber
- b—Size of air compressor
- c—Size of air box
- d—Size of power cylinder
- e—Position of exhaust ports
- D_1—Bore of air compressor cylinder
- D_2—Bore of power cylinder
- M—Mass of piston assembly

The equations of motion for the piston may be written as:

(1) $M(dx/d\theta) = \sum \text{Forces} = F_1(x) - F_2(x) - F_3(x) - F_4(\dot{x}) \mp F_5$ and

(2) $dx/d\theta = \dot{x}$

where $\dot{x}$ = Velocity of piston, in./sec and θ = Time, sec.

It remains to set up realistic analytical expressions for the force functions of Eq. 1. In general, they must be developed as functions of piston position, the design parameters, and suitable engine operating conditions.

The gas pressures in the various parts of the engine furnish the means for the evaluation of the force functions. For the evaluation of F_1, F_4, and F_5 single expressions can be used to represent the forces which are valid for all piston positions. The following expressions describe these forces:

(3) $F_1 = C_1/(a+x)^{n_1}$

(4) $F_4 = C_4\dot{x}$

(5) $F_5 = C_5$

where the constants C_1, C_4, and C_5 are functions of the operating conditions and n_1 is a polytropic exponent for the process.

For the evaluation of F_2 and F_3, a more compli-

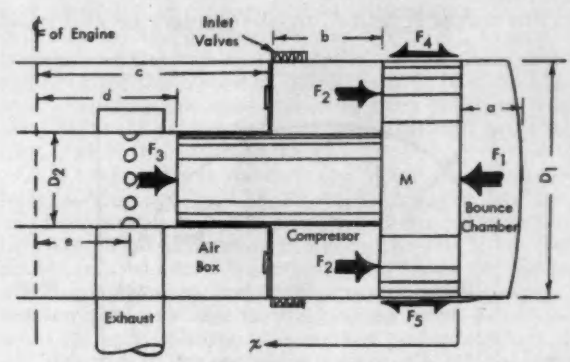


Fig. 5—Sketch of engine showing forces and dimensions considered in analysis.

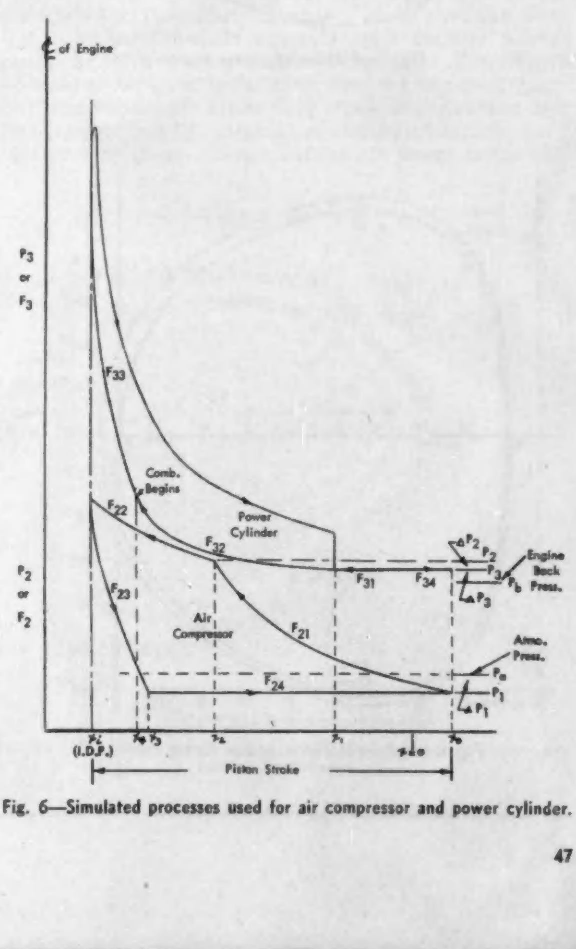


Fig. 6—Simulated processes used for air compressor and power cylinder.

Digital Computer---continued

cated situation exists. The pressures in the compressor and the power cylinder cannot be represented with a single expression for a cycle of piston motion. A sketch of F_2 and F_3 for various positions is shown in Fig. 6. Four separate idealized processes have been used to simulate what occurs in the compressor. The processes are related but the transition from one process to another is discontinuous because of the action of the intake and exhaust valves. A similar situation exists in the power cylinder.

The forces F_2 and F_3 must therefore be evaluated differently for various piston positions. These force functions may be summarized as follows:

(6)
a. $F_{21} = C_{21}/(b-x)^{n_{21}}$ $\quad x_0 \leq x \leq x_2$ for $\dot{x} \geq 0$
b. $F_{22} = C_{22}/(b+c-x)^{n_{22}}$ $\quad x_2 \leq x \leq x_i$ for $\dot{x} \geq 0$
c. $F_{23} = C_{23}/(b-x)^{n_{23}}$ $\quad x_i \geq x \geq x_3$ for $\dot{x} \leq 0$
d. $F_{24} = C_{24}$ $\quad x_3 \geq x \geq x_0$ for $\dot{x} \leq 0$

(7)
a. $F_{31} = C_{31}$ $\quad x_0 \leq x \leq x_1$ for $\dot{x} \geq 0$
b. $F_{32} = C_{32}/(d-x)^{n_{32}}$ $\quad x_1 \leq x \leq x_4$ for $\dot{x} \geq 0$
c. $$\frac{dF_{32}}{d\theta} = \frac{1}{(d-x)}\left[kF_{32}\dot{x} + (k-1)\,(AC\theta^*)\right]$$
$x_4 \leq x \leq x_i$ for $\dot{x} \geq 0$
and
$x_i \geq x \geq x_1$ for $\dot{x} \leq 0$
d. $F_{34} = C_{31}$ $\quad x_1 \geq x \geq x_0$ for $\dot{x} \leq 0$

where the constants C_{21}, C_{22}, . . . and the intermediate limits x_1, x_2, . . . are functions of the operating conditions and design parameters. n_{21}, n_{22}, . . . are polytropic exponents for the various processes; k is the ratio of specific heats, c_p/c_v; A is a combustion time constant; and $C(\theta^*)$ denotes the rate of energy released by a simulated combustion process in terms of θ^* which represents an arbitrary time (sec) used to specify the rate of energy release during a simulated combustion process.

Except for Eq. 7c, the force equations 3, 4, 5, 6, and 7 are simple functions which can be substituted directly into Eq. 1. They have been obtained with the assumption that the various compression and expansion processes can be suitably represented with polytropic type expressions.

The combustion process accounts for the differential equation, 7c. The process is simulated by a continuous addition of energy to the contents of the power cylinder. The process begins at x_4 (Fig. 6) upon the start of simulated fuel injection; it continues up to x_i (idp) and on to the time when the ex-

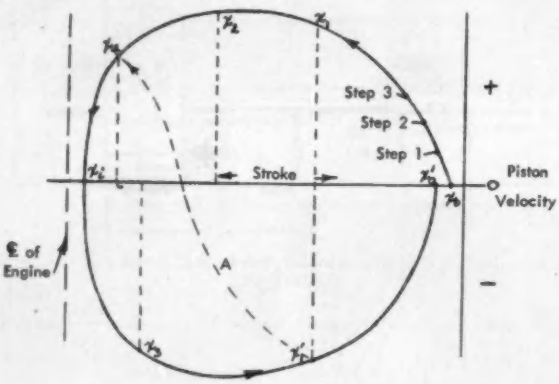


Fig. 7—Diagram of piston motion.

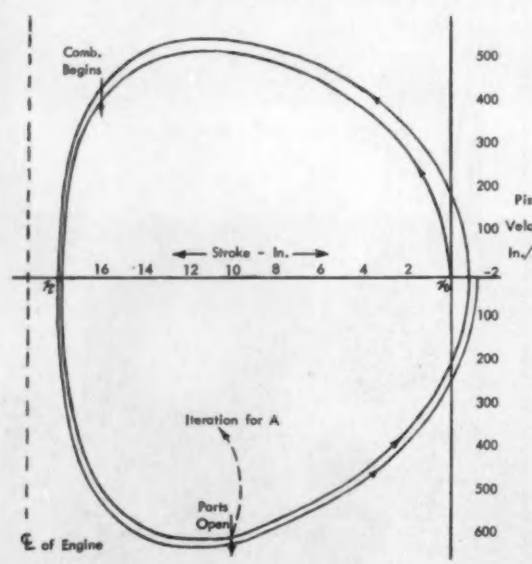


Fig. 8—History of piston motion during solution.

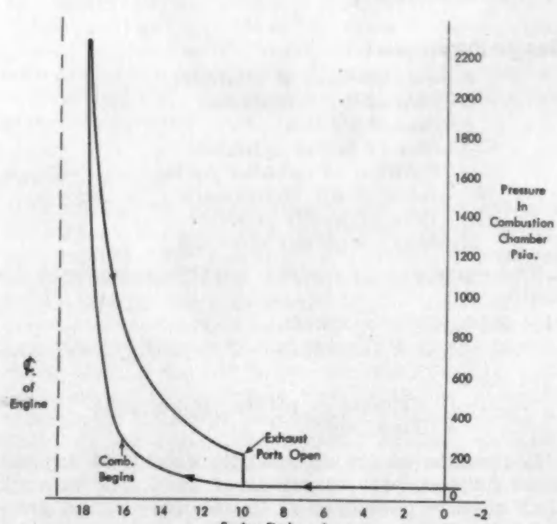


Fig. 9—Pressure-stroke diagram for simulated combustion process.

haust ports are uncovered. The simulation is made time-dependent in an attempt to realistically portray the actual combustion process.

The energy addition is specified in terms of the rate of addition as a function of time. It is fixed in the analysis mainly in terms of the heating value of the fuel and the fuel flow rate. The general nature of this function, which is symbolized by $C(\theta^{*})$ in equation 7c, has been found experimentally from indicator cards of free-piston engine combustion processes.

The role of the pressure losses included in the analysis is shown on the right of Fig. 6. The first loss occurs as atmospheric air flows through the compressor inlet valves. This effect is included in the analysis by expressing this pressure loss in terms of the percentage of the upstream pressure which is lost as a result of the friction process. Thus, the pressure at the start of compression, P_1, may be written as

(8) $P_1 = (1 - \triangle P_1)\, P_a$

In a similar manner, the pressure in the power cylinder during the scavenging process, P_3, can be expressed in terms of the engine back pressure, P_b, and the pressure loss coefficient applying to the exhaust ports and exhaust gas collector, $\triangle P_3$.

Further, the pressure required in the air compressor at the start of air delivery to the air box, P_2, can be expressed in terms of the engine back pressure and pressure loss coefficients $\triangle P_2$ and $\triangle P_3$. The coefficient $\triangle P_2$ reflects the loss for the compressor discharge valves and the inlet air ports.

Upon the selection of values for the design parameters and operating conditions to represent a given engine, all of the constants in the force equations may be evaluated and incorporated into Eq. 1. The equations of motion for the piston may then be written as:

(1) $M(d\dot{x}/d\theta) = f_1(x,\dot{x})$

(2) $dx/d\theta = \dot{x}$

(7c) $dF_{33}/d\theta = f_2(F_{33}, x, \dot{x})$

A solution comparable with the complex nature of f_1 and f_2 may now be contemplated.

The Solution

The diverse nature of the expressions obtained for the forces, specifically Eqs. 6 and 7, thwart any hope for a general solution of the equations of motion. Particular solutions can be obtained however with numerical methods. The method of Runge-Kutta was employed and the problem was programmed for the IBM 704 digital computer.

A small time change, $\triangle\theta$, was taken as the independent variable for the calculation of each small step in the development of the solution. The solution was begun at x_o, Fig. 6, where the initial value of $\dot{x}$ equals zero. The initial value of x_o must be assumed since the odp for the operating conditions and engine configuration, to which the solution refers, is now known. Starting from these initial conditions the piston motion in terms of position, velocity, and acceleration is charted in successive small steps (Fig. 7).

As each of the intermediate limits, x_1, x_2, and such, is reached the proper force function is substituted in Eq. 1. When x_4 is reached, signalling the beginning of combustion, the differential equation 7c is included with the equations of motion 1 and 2 for simultaneous solution. x_i (idp) is located when $\dot{x}$ equals zero.

As the solution is continued, x_o (Fig. 7) is again reached and a check on the validity of the initial assumption for x_o can be made. If x'_o is sufficiently close to x_o then the solution is complete. If a closer check is desired then a new solution can be obtained by using x'_o in place of x_o. This procedure is continued until the odp is located with the desired accuracy (Fig. 8). The final checked solution represents the steady state operating condition.

An additional process is required in the course of the solution. It concerns the simulated combustion process. In the specification of the $C(\theta^{*})$ function in terms of the fuel flow rate, Eq. 7c, the total time required for the piston to travel from x_4 to x_i and on to x', must be assumed. During each solution this time interval as predicted by the solution is compared with the assumed value.

If a correction is needed, the value of the combustion time constant, A, Eq. 7c, is changed and the solution reverts to x_4 for a re-run of the combustion process. This process is indicated in Fig. 7 by the dotted path A. In a typical solution three "A" loops are required for each simulated combustion process. Obviously, a new combustion process must be simulated for each solution of a cycle of piston motion.

A diagram of the complete history of a single solution of the equations of motion, Fig. 8, illustrates the general nature of the procedure. The pressure-stroke diagram of the power cylinder for the final solution, Fig. 9, illustrates the realistic nature of the simulated combustion process. It is evident that the solution depends upon several factors which might be termed computation constants. The allowable error for x_o and the step size, $\triangle\theta$, are examples. If these values are made very small the solution will be accurate but the amount of computation required will be very large. If the values are made large, the

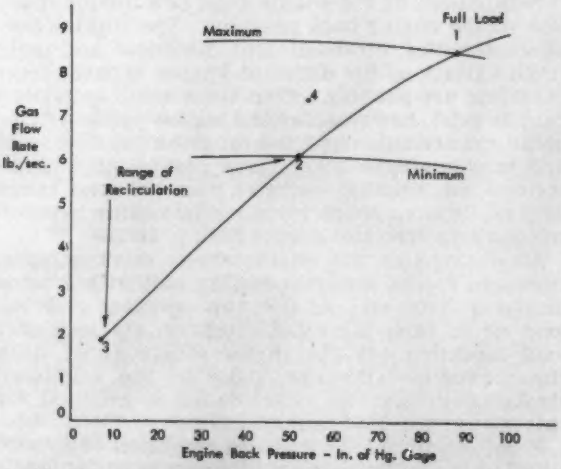


Fig. 10—Flow characteristics for a 1000 hp free-piston engine-gas turbine combination.

Digital Computer---continued

computation will be greatly reduced and the accuracy will be sacrificed. Solutions in which only these factors are varied, one at a time, enable feasible values to be chosen for these computation parameters.

Computed Engine Performance

The solution of the equations of motion provides the necessary information for the evaluation of engine performance. The actual calculations are performed by the computer, with two exceptions, from the results obtained for the final checked solution, Fig. 8. The following results are obtained taking into account any specified amount of recirculation or inlet throttling which may occur.

1. History of piston motion, position, velocity, and acceleration as a function of time.
2. Inner dead point, idp, in.
3. Outer dead point, odp, in.
4. Stroke, in.
5. Speed, cycles/min.
6. Gas flow rate, lb/min.
7. Air inducted, lb air/stroke.
8. Air trapped, lb air/stroke.
9. Scavenging ratio, lb air into combustion chamber/lb air trapped.
10. Air temperature prior to release, R.
11. Maximum combustion chamber pressure, psia.
12. Fuel flow rate, lb/min.
13. Gas horsepower (computed by hand).
14. Gas specific fuel consumption (computed by hand).

Comparison of Computed Results with Engine Test Results

When a gas turbine is connected to the exhaust line of a free-piston engine, the engine must operate under an additional constraint. For now, in addition to the control imposed by the stabilizer and provision for recirculation or throttling, the gas flow rate produced by the engine must be a unique function of the engine back pressure. The turbine flow characteristics establish this function and only small variations for different engine exhaust temperatures are possible. Even these small variations cannot exist, however, for the engine exhaust temperatures are uniquely fixed for given gas flow rates and back pressures. For these reasons an engine-turbine combination operates over the load range with an unusual characteristic relationship between the gas flow rate and engine back pressure.

An example of this characteristic relationship is shown in Fig. 10 for an operating unit with a rated output of 1000 hp. As the unit operates over the load range from the rated condition (1) to a part load condition (2) the engine stroke varies from the maximum allowable value to the minimum stroke condition. No recirculation is required for this part of the load range.

From condition (2) down to condition (3) recirculation is used in increasing amounts to achieve a compatible flow characteristic between the engine and turbine. The minimum engine stroke is maintained throughout this portion of the load range. A part load condition such as (4) could not be produced with the engine-turbine combination even though the engine could operate under these conditions.

Now, in order to compare the computed results with engine test results, the control imposed on the actual engine in the form of stabilizer design, turbine characteristics, and provision for recirculation must be duplicated in the computed results. The engine simulated with the computer operates with no control save that provided by the values given the operating conditions. The computed results were obtained using representative values for all of the fixed design parameters and operating conditions. The following operating conditions were used to control the computer simulation in a manner identical to the regulation imposed upon the operating engine.

1. The selected bounce pressure, P_{sb}, was made equal to the test value in all cases. This is a function of stabilizer design.
2. The fuel injection timing was used to fix x_i according to test conditions.
3. The pressure losses attributed to the several valves and ports were adjusted from the values used at full load according to the gas flow rates at all part load conditions.
4. At each of the several engine back pressures the flow rate of the fuel was varied in successive simulations until the gas flow rate predicted by the simulation equalled the test value as shown in Fig. 10.

The results of the computer simulation are shown with the engine test results in Figs. 11 and 12.

Prediction of Free-Piston Power Unit Performance

The general problem of using the computer simulation to predict the performance of an engine-turbine combination is complicated by the necessity of control. The main control elements may be listed as:

1. The turbine. This fixes the relationship between the gas flow rate and the engine back pressure.
2. The stabilizer. This fixes the relationship between the selected bounce chamber pressure and the engine back pressure.
3. Recirculation or throttling. These controls can be used to independently control the gas flow rate.
4. Fuel rate. This is the main independent control for the unit.

Disregarding the control imposed by the turbine for the moment, a series of solutions can be obtained which illustrate the nature of the relationship between the selected bounce chamber pressure and the engine back pressure (Fig. 13).

These results apply to a particular simulated engine and were obtained with the trapped fuel-air mixture ratio maintained constant. Similar results could have been obtained for a given fuel flow rate. Obviously, all of the performance results such as, engine stroke, speed, exhaust gas temperatures, specific fuel consumption, and such are available from the solution for each of the points shown in Fig. 13. In this particular discussion, however, the gas flow rate is the most important characteristic.

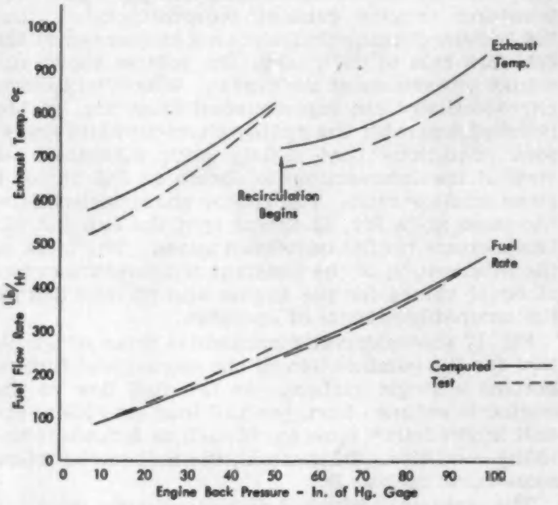


Fig. 11—Comparison of computed results with engine test performance.

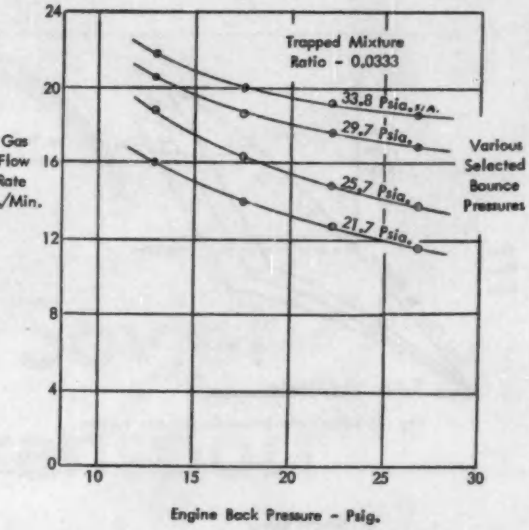


Fig. 13—Computed performance for a free-piston engine.

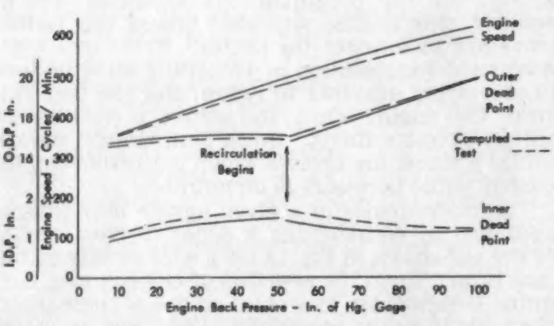


Fig. 12—Comparison of computed results with engine test performance.

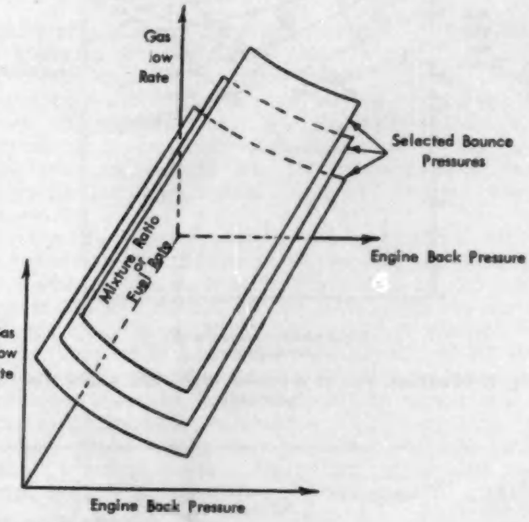


Fig. 14—Nature of the performance of a free-piston engine.

A more descriptive picture may now be obtained by adding another dimension to the results indicated in Fig. 13. This requires results of the same type for various values of the fuel flow rate or mixture ratio. Each selected bounce pressure now operates to generate a surface. Obviously other possible surfaces can be shown such as engine stroke, speed, and the like, and the surfaces will be bounded by such practical limitations as maximum and minimum possible odp and the allowable minimum idp. Within these practical limitations, however, a given engine may operate at any point in the three dimensional space. Where it will operate depends upon:

1. The back pressure.
2. The rack setting.
3. The selected bounce pressure.

Small variations caused by other engine variables may modify these general characteristics somewhat. Typical examples are the effect of inlet air conditions in terms of pressure and temperature. Another is fuel injection timing which is simulated by the point where combustion begins, x_i. (con't.)

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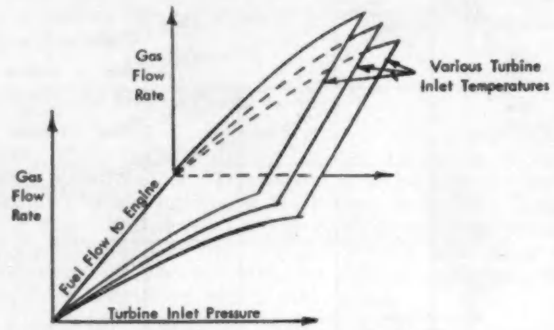


Fig. 15—Flow characteristics of gas turbine.

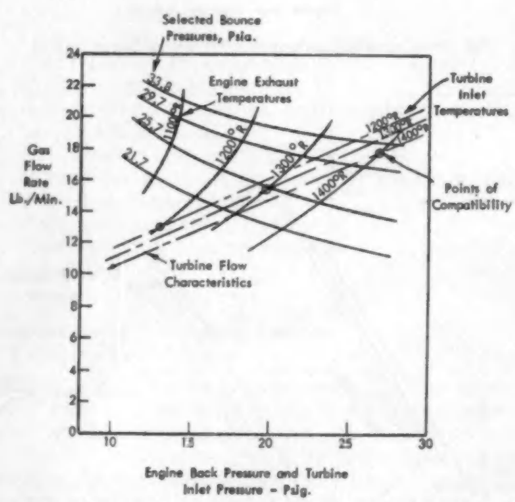


Fig. 16—Combined plot of computed engine and turbine flow characteristics.

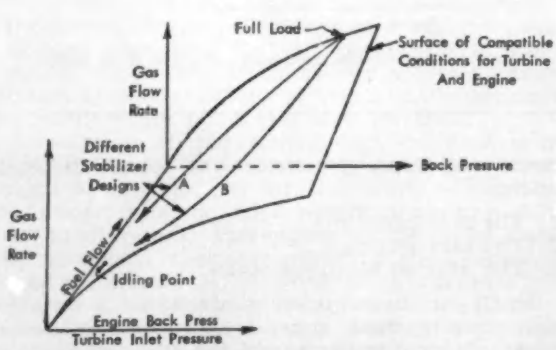


Fig. 17—Nature of region where engine and turbine can operate in combination.

The control imposed by the turbine can now be added. Fig. 15 illustrates the flow characteristics of a fixed nozzle turbine for various inlet gas temperatures (engine exhaust temperatures). Since the turbine characteristics are not influenced by the fuel flow rate to the engine, the sufaces shown are simple projections of the curves. When the turbine characteristics are superimposed upon Fig. 14, the intersections with the engine characteristics represent conditions that satisfy both machines. A view of the intersections is shown in Fig. 16 for a given mixture ratio. The engine characteristics are the same as in Fig. 13 except that the exhaust gas temperature results have been added. The locus of the intersection of the constant temperature curves of equal values for the engine and turbine defines the compatible points of operation.

Fig. 17 shows that the compatible areas of operation for the combination of the engine and turbine become a single surface. As the fuel flow to the engine is reduced from the full load condition, the unit might follow some curve such as A down to the idling condition. In contrast, the unit might follow some curve such as B.

The manner in which it does move down from full load is controlled by the design of the engine stabilizer. This device controls the selected bounce chamber pressure as a function of the engine back pressure. The stabilizer can therefore be designed to control the operation of the engine at part load according to certain precepts. These may include operation at maximum fuel economy conditions or at particular part load power outputs.

The recirculation or throttling controls are needed to extend the operating range of the engine-turbine combination. At some point along the path of operation from full load (see path A, Fig. 17, and point 2, Fig. 10) the minimum odp condition will be reached (the engine will stall unless the pistons move out to uncover the ports). From this point downward recirculation or throttling must be used in increasing amounts to reduce the gas flow rate from the engine while the stroke is maintained within operable limits. Since both control devices utilize a throttling process which is irreversible, the control while necessary is undesirable.

The performance of a given engine may thus be predicted by constructing a series of plots similar to the one shown in Fig. 13 for a wide variety of fuel flow rates. Upon the selection of the full load condition (represented by a point on one of these plots) the turbine size is essentially fixed. For, to match the engine at this full load point the turbine nozzle size must be selected.

The turbine characteristic can now be developed on each of the plots for different fuel rates as illustrated in Fig. 16. In turn, the characteristics of the stabilizer may be selected and the performance of the engine-turbine combination over the entire load range is known. Different full load conditions can then be selected and the new turbine characteristics and stabilizer designs can be used to investigate a variety of engine-turbine combinations.

A detailed development of the equations and constants used in this article can be found in the author's original paper.

To Order Paper No. 5A ...
... on which this article is based, turn to page 5.

3 Russian Aircraft Designers and Their 6 Soviet Transport Airplanes

Secor D. Browne

W. H. Nichols Co.

SINCE June 1955, when the Soviets first flew the Tupolev Tu-104, five other jet transport aircraft have appeared in the Russian skies. Of these six aircraft three, the TU-104, TU-104A, and Tu-110, are turbojets, and three, the AN-10 ("Ukraina"), IL-18 ("Moskva"), and TU-114 ("Rossiya"), are turboprops.

The huge land mass of the Soviet Union and its still rudimentary network of land transportation lend special importance to these aircraft and indeed all forms of air transportation. The influence of vast space and distance is not readily appreciated in the countries of the West possessing dense networks of rail and road connections which give rapid access to the national centers of government and industry. The Canadian practice of delivering equipment and supplies to the mining centers in remote areas by air provides a small-scale example of the function assigned to air transportation in the Soviet Union. It serves to link the newly developing and otherwise inaccessible industrial areas of the Soviet Union to the sources of supply. In many such areas air transport provides the major if not the only means of delivering machinery, construction materials, tools, and other necessities, not to mention labor and supervisory personnel.

It is true that in its 40 years of existence the Soviet Union has materially expanded its network of rail, highway, and waterway communications—even if at a tremendous price in terms of human lives, for such construction has been carried on almost exclusively by forced labor. Nevertheless, until and unless many additional thousands of miles of communication arteries should be constructed, high-speed air transportation must continue to be a basic requirement for the political and economic survival and progress of the Soviet Union.

If to the area of the Soviet Union itself, the areas of the satellite countries and of the countries in which the Soviet Union is actively establishing political and economic domination be added, the basic pressure behind the tremendous expansion programs for the Soviet Aeroflot become even clearer.

Lastly, the factor of propaganda is present in every sphere of Soviet activity. In attempting to persuade the uncommitted masses of the world of the efficacy of the communist system, success in the air is counted upon to pay dividends out of proportion to the investment of resources and effort. A TU-104 on the apron at Cairo or New Delhi may be more persuasive than shiploads of American wheat at the docks in Alexandria or Calcutta. Soviet writings on aviation make abundant reference to the "air ocean," a concept not invented by the Soviets but dating back to the great Russian scientist Mendeleev

This is part I of a two-part article. Part II in next month's issue will deal with Andrei Tupolev and the TU series of transport airplanes.

in the 1880's. It is the military, political, and economic domination of this "ocean" which the Soviets intend to win. The jet transports are important means to that end.

In aviation, as in all areas of human activity, the Soviets would persuade the world that the Beginning was October 1917—or shortly thereafter. This approach makes it somewhat inconvenient to explain the contributions of men long dead, or men of Russian birth still very much alive and still contributing to aviation—but not in the Soviet Union—such as Igor Sikorsky. Soviet aviation histories and the Great Soviet Encyclopedia describe in detail the multi-engined World War I heavy bomber which was test flown in December 1913 and which certainly represented one of the great aeronautical achievements of its time. No mention, however, is made in the Soviet accounts of Sikorsky nor of any other Russian aircraft engineer and scientist who survived the Revolution but did not join the Soviet cause. Zhukovski, Tsiolkovski, Chaplygin, and other pioneers of Russian aviation who, after the Revolution, continued their work under the new Soviet regime are portrayed as only reaching full productivity after the shackles of tsarist repression and indifference were removed.

In July of 1957, the first two Soviet turboprop transports, the Ilyushin Il-18, known as the "Moskva," and the Antonov AN-10 "Ukraina" were first revealed to the West at the same time as the TU-110.

The designer of the "Moskva," **Sergei Vladimirovitch Ilyushin** (1894–)has a long aviation background, beginning as a hangar hand and mechanic in tsarist military aviation (1916). In 1917 Ilyushin passed his pilot's examination and in 1919 transferred his talents to the service of the Red Army. In 1921 he began formal engineering training in the Moscow Institute of Engineers of the Red Air Fleet from which he transferred to the well-known Zhukovski Military Air Engineering Academy.

His active career as an aircraft designer began in 1932 with his work on the design of a twin-engined transport airplane which eventually made a num-

Secor Browne, Engineer and Linguist, Compares Engineers and Engineering

SECOR D. BROWNE of the W. H. Nichols Co. prepared the report appearing on these pages and presented it to the SAE Aircraft Activity Committee at its meeting on January 16. Browne speaks fluent Russian and is Special Assistant to the director of libraries of the Massachusetts Institute of Technology on Russian technical literature.

THE Soviet aviation industry is very different from the aviation industry in the United States, Browne pointed out in presenting his paper. Taking Aircraft Activity Chairman Harrison Holzapfel as an illustration, Browne explained that if Holzapfel were working in the Soviet industry, he'd probably be a military officer, a faculty member of an engineering school, and a director of a research institute, as well as a manufacturer.

If he were required to design and produce a piece of aircraft equipment, he'd know that there are severe penalties for failure. So he'd tend to insure the success of his design by starting from a conservative base. He would develop a rugged, heavy design, sure to work.

If he needed an item similar to one already being made by the ground-vehicle industry, Browne continued, our engineer-manager would more likely make it in his own facilities because he can't easily "move sideways" in the Russian vertically organized system. There's no equivalent of SAE, and an aircraft manufacturer isn't likely to have much contact with another industry.

He probably has a pretty good knowledge of what his opposite numbers in the United States are doing, Browne explained. Russia apparently has as many as 2500 full-time translators plus enough spare-time translators to bring the total to 10,000–20,000. Information centers receive practically all technical publications from the United States, Great Britain, France, and Germany. They translate them, abstract them, and circulate the abstracts to everyone registered as interested in the subject.

Our laws hamper us from studying Soviet technical literature as they do ours, Browne explained. Our laws prohibit the sending of "subversive" material through the mails. So even a textbook with a political preface is hard to get. Bookstores aren't eager to handle Russian books.

Once Soviet publications do get into U.S. libraries, it's difficult to get them even if you read Russian, Browne said. The libraries transliterate the Russian alphabet letters to Latin letters for cataloging purposes. Then when the library messenger is sent to get a Russian book from the stacks, he can't recognize the Russian letters from his slip showing their Latin counterparts. So you really need a stack permit to get at the Russian publications.

More important than any comparative statistics on the number of engineers graduated in Russia and in the United States are the figures on the many more technicians trained in the Soviet Union, Browne pointed out. In 1958 there will be about 180,000–200,000 graduates of post-high school technical institutes in Russia and only 10,000–15,000 in the United States.

In answering questions asked him by Committeemen, Browne brought out these facts:

—When Dr. Killian left M.I.T. to become scientific adviser to the president, the school was paying him about five times what it paid the man who cleans the lavatories. In the Soviet Union a professor of aeronautics may earn 20 or more times as much as a man who cleans lavatories. The Russian professor might have a car, but the lavatory cleaner would have difficulties in buying one even if he had the money.

—A Soviet engineer visiting M.I.T. recently men-

ber of long-range flights, including one from Moscow to America in 1939. This aircraft was followed in 1934 by the Il-4 twin-engined bomber, designed in 1933, and the Il-2 dive bomber, both of which played a considerable role in Soviet World War II aviation. The Il-12, twin-engined transport resembling the DC-3, long was the mainstay of Soviet military and civil air transport. In civil transport it has been superseded by the Il-14 which is an 18-passenger twin-engined transport with tricycle gear, and in its latest version the Il-14M carries 24 passengers. The Il-18 "Moskva" is the latest transport and the first turboprop designed by Ilyushin. Ilyushin's work has been rewarded by promotion to the rank of lieutenant general in the Engineering Technical Service, the title of Hero of Socialist Labor, and the usual medals and orders. He is also a professor at the Zhukovski Military Air Engineering Academy—once again the "multiple hat" responsibilities of the Soviet scientific leader.

The Il-18 "Moskva" is a four turboprop transport to be produced in both a 75-passenger luxury version and a 100-passenger tourist configuration. Its cruising speed is given as 375 mph at 26,000 ft. There are five usual stations in the cockpit: the navigator's station is behind the pilot's, the radio operator sits behind the co-pilot, and the flight engineer sits between the pilots on a jump seat. Directly aft of the cockpit is a small baggage compartment, a coat rack, and a lavatory for the crew. There are two other lavatories located in the tail aft of the main passenger cabin.

Aft of the crew area is a cabin for 10 passengers, seated five abreast, three and two seating as in the main cabin aft of the galley which separates the two passenger cabins. The galley is equipped with electric refrigerator, electric hot plates and oven, and has storage space for thermos containers of hot and cold foods. The main cabin has 13 rows of five-abreast seats mounted on rails. Seats are not only removable, but additional rows of seats can be installed on these rails to increase the seating capacity. By adding five more rows of seats, the total capacity is presumably increased from the 75-passenger to the 100-passenger tourist version. The aisle width is about 20 in. and the windows are approximately 16 in. in diameter. Both passenger cabins have provision for hanging infant cradles. Passengers have individual reading lights, face ventilators, stewardess call buttons, and an individual folding table. Although more has been done to modernize the interior of the "Moskva" than other Soviet transports, the style is still predominately Pullman Renaissance.

At an airplane altitude of 16,000 ft the cabin is held at sea level, at 26,000 ft the cabin is pressurized to 5000 ft, and at 33,000 ft an 8000 ft cabin altitude is maintained. Refrigeration is by air expansion turbine.

The airplane's tricycle landing gear with steerable nose wheel is operated hydraulically, retracting forward. In case of hydraulic system failure, gravity and the opposing air stream take care of lowering the gear—a safety feature much emphasized. When the aircraft is parked, controls can be locked by remote control from the flight station, but flight controls do not have hydraulic assist. The hydraulic system for raising and lowering the landing gear, braking, nosewheel steering, and for operation of the windshield wipers has a working pressure of 3000 psi. Emergency braking is carried out by use of compressed gas.

For wing, windshield, empennage, prop, and spinner anti-icing an electrical anti-icing system is used. Engine air inlets are protected by hot air. The electrical anti-icing system allows an input of 6 to 14 kw per sq m (1.1956 sq yd). There are automatic controls to prevent over-heating, but normal operation is manual according to warning light indication. Two generators per engine, which are also used as starting motors, give a total d-c electrical supply of 130 kw. Inverters give 115-v, 400-cycle single-phase power for windshield, prop, and other anti-icing and a "group of other devices." The latter must include the radar and communications equipment to which non-specific reference is made in pointing out the all-weather flying capabilities of the "Moskva."

The "Moskva's" four 4000-eshp NK-4 turboprop engines were designed and constructed under the supervision of **N. D. Kuznetsov**. Their reversible

in Russia and the United States

tioned having a five-room apartment (in a country where sometimes several families have to share one apartment), a television set, a radio, a tape recorder, a phonograph, the use of a car, a summer home, and the services of a nursemaid for his one child. He is a senior staff man from a technical institute.

—Perhaps some Soviet scientists excel in their fields because for them science is the principal escape. In Russia, there are no lodge meetings, no informal political party activities, and few of the other diversions Americans have. Soviet engineers seem to have equal depth of scientific knowledge but perhaps less inspiration.

—The big Soviet electronic computers use the same types of systems that U. S. electronic computers do.

—The Russian missile program uses German experts about as we have done. They are now using mostly Russians, trained in part by the German scientists.

—Aeroflot, the air transport arm of the Russian air force, is apparently switching from IL-12's (about like DC-3's) and IL-14's (about like Convair 240's) to jet transports. Production is well under way. The new transports are a "must" for transportation needs—and a very useful propaganda tool, too. Aeroflot may cut fares drastically on inter-country flights to attract business away from the competition.

—Russian technical books are priced low, both in rubles in Russia and in dollars in foreign bookstores in this country. Probably the prices are low because the print orders are high, perhaps 50,000–100,000 for many texts.

—Soviet technical books are printed in non-Russian languages when such effort can contribute to Soviet political and economic aims, although they are not printed in English.

propellers have electric pitch control. The engine lubrication system holds $8\frac{1}{2}$ gal and uses air-oil heat exchangers and multiple element lube and scavenge pumps. Located in the wings, the fuel tanks give the aircraft a range of 1250 miles with a 14-ton payload and a range of 3100 miles with a "lesser" payload. The weight of the aircraft is given as 58 tons gross and 28 tons without fuel or payload.

In view of the many "unimproved" airports in the Soviet Union which have short runways (or do not as yet have hard surface runways), the unspecified "low" take-off and landing speeds of the "Moskva" and its claimed ability to take off fully loaded in 2300–2500 ft and land, also fully loaded, in 1650–2000 ft is of considerable importance, especially as these characteristics are combined with a spread of 30 ft between the right and left gear—a feature which appears to have been designed specially for rough terrain.

Much emphasis has apparently been placed on safety in the design of this aircraft. The selected powerplant is considered adequate for take-off and climb on only three engines to 20,000 to 26,000 ft with the ability to continue cruise on two engines at altitudes to 16,400 ft. Double cabin walls and windows are designed for safety. Great attention has also apparently been given to safety against fire, with all fuel being carried in the wings and with the use of titanium in isolating the structure from the powerplants. In the cabin all furnishings and finishes are made of non-inflammable materials.

The third turboprop airplane which made its debut recently, the AN-10 "Ukraina," appears to have been designed with much the same operating conditions in mind as the "Moskva." It is stated that the fully loaded "Ukraina" can take off in 2150 ft and land at 105 mph. Its gear is much of the same paddle-footed design as that of the "Moskva," making it suited to uneven terrain and short runways.

The head of the design group responsible for the "Ukraina," **O. K. Antonov**, has had a long career, but enjoyed very few mentions in the history of Soviet aviation. His turboprop transport is a departure from other Soviet jet transport aircraft, being a high-wing monoplane. Antonov has also recently brought up to the mock-up stage a very small brother of the "Ukraina," the eight-place, twin-piston-engined "Plechka," another high-wing monoplane. This structure therefore may have become an Antonov specialty. The 84-passenger "Ukraina" (there is a 126-passenger version projected) is stated to cruise at 375–400 mph at altitudes of 26,000 to 33,000 ft. Normal gross weight is 51 tons and maximum payload is 13 tons. The range at 375–400 mph with a 12-ton load is 1250 miles; with a 10-ton load, 1900 miles; and with an 8.2-ton load, up to 2100 miles.

The "Ukraina's" three passenger cabins are separated by partitions with curtained doorways. Together with framed pictures affixed to the walls, the curtains give the interior a somewhat "homey" look enhanced by a special "kiddy corner"—as a section of one cabin is literally called. The forward cabin seats 25, two seats on the left side opposite a lavatory, then a five-seat row (three and two), and then three rows of six seats (three and three). Aft of this cabin is a passenger entrance, coat rack, and the galley. Next comes the 46-seat main cabin with its "kiddy corner"—actually a pair of divans. The "kiddy" section is followed by a row of four seats (two and two), presumably for the kiddies' happy parents, then by six rows of six seats (three and three), and lastly by two groups of three seats on the right-hand side opposite the other passenger entrance.

Another lavatory and a cabin seating 13 is located aft of the main cabin: two seats balancing the lavatory as in the forward cabin, two rows of four seats (two and two), and a final row of three seats against the bulkhead. These seats are all removable, permitting ready use of this cabin as a cargo compartment. Each seat is individually adjustable, has its own reading light and radio headphone. Ashtray in the armrest, switches for the reading light and radio, and stewardess call button complete the appointments. It is a little difficult to envisage how the seating capacity of this aircraft can be increased to 126.

Considerable attention has been given to rapid access to the pressurized cargo compartment in order to enhance the "Ukraina's" utility as a short-haul carrier. The cabin is pressurized from the engines, with pressure and temperature automatically controlled. It is stated that the engine bleed air also heats the cabin, but means of cooling are not specified.

The landing gear of the "Ukraina" is specially designed for rough terrain and sod runways, and the wheels have automatic braking systems. The gear is hydraulically operated as is the tail skid which can be retracted. Working pressure of the hydraulic system is 2100 psi.

The powerplants currently used on the "Ukraina" are a mystery. At first they were said to be the same Kuznetzov turboprops which are used on the "Moskva." Later they were declared to be the more powerful turboprops designed by Ivchenko. All that can be said is that each of the "Ukraina's" four engines is at least 4000 eshp with electrically controlled and reversible propellers, and that the engines use a system of electric starter-generators. It has been stated that the "Ukraina" can cruise on two engines at altitudes up to 20,000 ft. A complete electrical anti-icing system, similiar to the system employed on the "Moskva" is another feature of the "Ukraina." As a last note, the crew of this plane includes a pilot, a co-pilot, a navigator, a radio operator, and two cabin attendants—but no flight engineer.

No usual statistical measures are available for an over-all estimate of performance of the Soviet turbojet and turboprop aircraft in actual airline operation, nor of the number of the now-available operational aircraft in these categories. Familiar economic considerations which control Western civil aviation do not restrict our Soviet competitors, and the very existence of aircraft described here is sufficient evidence of Soviet capabilities in the jet transport era. The jet age aircraft represent the opening Soviet bid for commercial and political domination of the "air ocean." With *complete* control of human and material resources, the Soviet rulers can allot, and appear to be allotting, the means considered necessary to this particular end.

This is the kind of competition which faces the aircraft and air transport industry of the Western world.

Fuels, Lubricants Keep Pace With Design Trend Demands

Analysis of 10-years comparable Texas Co. performance test data points up current problems; reveals potency of cooperative engineering attack.

Based on paper by

E. M. Johnson and

C. W. Mortensen

Texaco Research Center

PASSENGER-car design trends of the last decade have greatly increased the stringency of fuels and lubricants requirements. V-8's with automatic transmissions have been equipped with power steering, nonspin differentials, ball-joint and torsion-bar suspensions—and air conditioning. Octane requirements are getting close to 100, full-throttle brake traction has nearly doubled. Operating temperatures have increased, except for certain fuel components.

All these innovations have brought continuously changing problems to fuels and lubricants engineers, who, in turn, have recorded consistent progress in meeting them.

Surface ignition, for example, is one of the fuel problems which has been gaining in prominence as compression ratios and octane requirements have risen. As ratios approach 12/1, engines become more susceptible to surface ignition. Some of the best fuels known today might not be able to eliminate entirely surface ignition in 12/1 compression ratio engines.

To illustrate: Fig. 1 shows cumulative surface ignition counts for two widely different fuels—which were run in a 12/1 compression ratio engine in a current model car on a simulated city-type driving schedule. One fuel had a moderate aromatic content; the other was a paraffinic stock. Each contained 3 ml tel per gal. ASTM Research octane number of the first was 106; of the second, 105. Both satisfied the spark-ignition octane requirement of the engine.

Result: There was no significant difference in surface ignition rate between the two, despite the wide variation in composition.

The surface problem to be faced in 12/1 compression ratio engines is far from solved. Considerably more work is needed.

The vapor-lock problem, on the other hand, is less severe than at the beginning of the last decade. Newer cars, which have fuel and coolant systems in

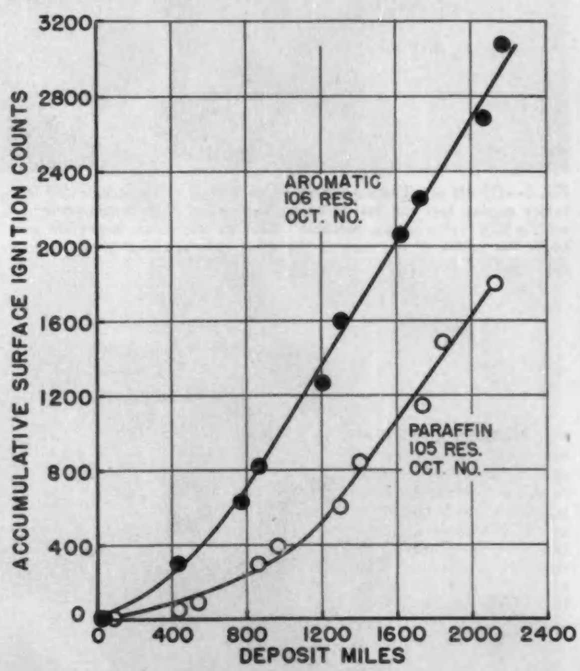


Fig. 1—Cumulative surface ignition counts for two widely different fuels. No significant difference in rate is shown. In both cases, surface ignition was clearly audible, as well as observable with instrumentation.

good condition, have lower incidence rates than cars that are a few years older.

Also, antiwear and load-carrying characteristics of oils have been definitely improved to meet the increasingly severe requirements of satisfactory valve train performance. Problems involve cam lobe, cam follower, and rocker arm shaft wear as well as cam follower and rocker arm shaft spalling and galling.

Figs. 2–4 demonstrate some of the improvements that have been made.

Valve train lubrication problems have been severe. But a combination of mechanical design, metallurgical advances, and oil improvements have now reduced them to significant proportions.

Deposits, of course, represent another continuing problem. Work has been steady to improve the low-temperature deposit resistance of both oils and fuels.

. . . And advances have been made. Figs. 5 and 6 point up the character and scope of such advances.

Extended use of automatic transmissions also has established an entirely new set of lubrication requirements. The fluid must act as a lubricant, a coolant, a hydraulic medium, and a power-transmitting medium.

New seal materials, too, have had to be explored and developed as operating temperatures have risen. And, as they have been developed, they are not always compatible with the lubricant.

The amount of power transmitted by rear axles has gone up considerably—but the size of the axles hasn't. Result: the lubricant has to provide improved load and antiwear characteristics. The universal joint, too, has been affected by the trend of rising horsepower. Its power transmission capacity has not kept pace with the rapid advances in engine output. Early failures have been experienced in some cases.

The new lubrication requirements imposed by power steering are, in many respects, similar to those imposed by automatic transmissions. So, automatic transmission fluids have been widely used for power steering units. Eventually, however, steering may have its separate and distinct fluid—because automatic transmission fluid requirements are becoming more and more stringent.

Throughout the range of new fuels and lubricants problems caused by car design trends, in other words, measurable progress toward solutions have been made . . . and solutions have been arrived at in many instances.

- Fuels have been improved, particularly with respect to antiknock value.
- Motor oils have greater wear and scuff resistance and higher detergency.
- Automatic transmission fluids have undergone continuous modification to improve oxidation stability, antiwear properties, and other characteristics.
- Rear-axle lubricants have been modified to provide greater antiwear and load-carrying capacities.

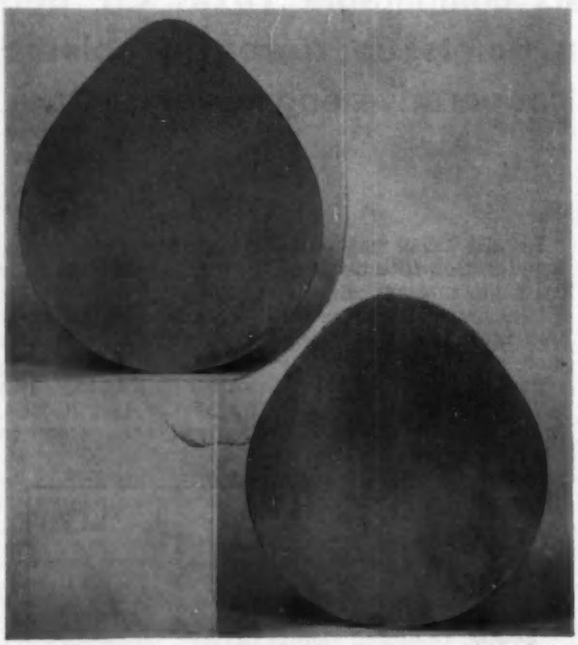


Fig. 2—Effects of oil improvement on cam lobes in an accelerated laboratory engine test run for 24 hr at high speed, high temperature, and with a 50% value spring overload. Cam on left shows negligible wear, while the profile of the nose of the other cam has been almost entirely destroyed.

Fig. 3—Range of oil performance in prevention of spalling and wear of cam followers obtained from simulated road operation on a laboratory engine. Observing from left to right, it is apparent that oil is a critical factor in this area of engine lubrication.

- New lubricants have been developed to replace chassis lubricants proved inadequate for new design components.
- New lubricants have been developed to meet the needs of new accessories.

This pace-keeping progress has been possible only through the spirit of close cooperation that exists between the passenger-car and petroleum engineers. Automotive progress will probably continue at the same pace in the years ahead. And, as it does, this same cooperative effort will permit fuels and lubricants to satisfy new exigencies as they arise.

To Order Paper No. 12A . . .
. . . on which this article is based, turn to page 5.

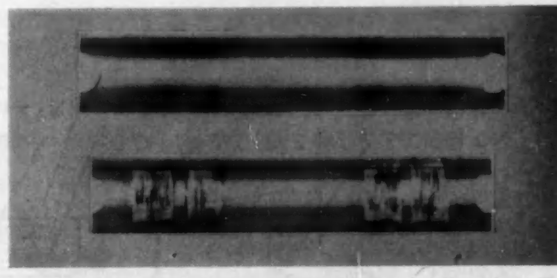


Fig. 4—Effects of oil performance on rocker arm shaft assembly. The lower illustration depicts typical scoring and galling experienced in 100-hr moderate-speed, no-load laboratory test with an inadequate lubricant. Upper illustration shows almost total prevention of wear and galling with use of current motor oils.

Improvement in Low-Temperature Deposit Resistance

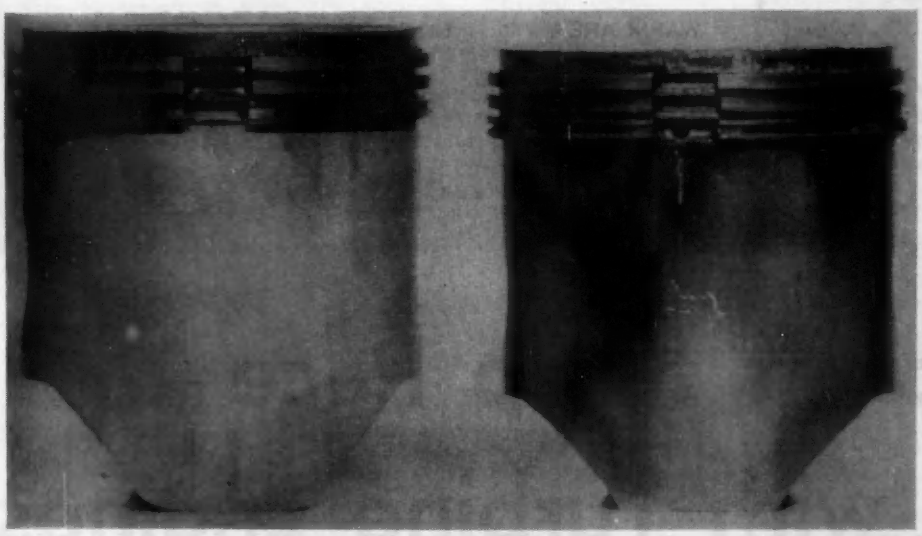


Fig. 5—Improvement is shown in low-temperature deposit formation. Clean piston at left resulted from running on same fuel and oil as did dirty piston at right—except that, in case of the clean piston, proprietary additives had been blended in.

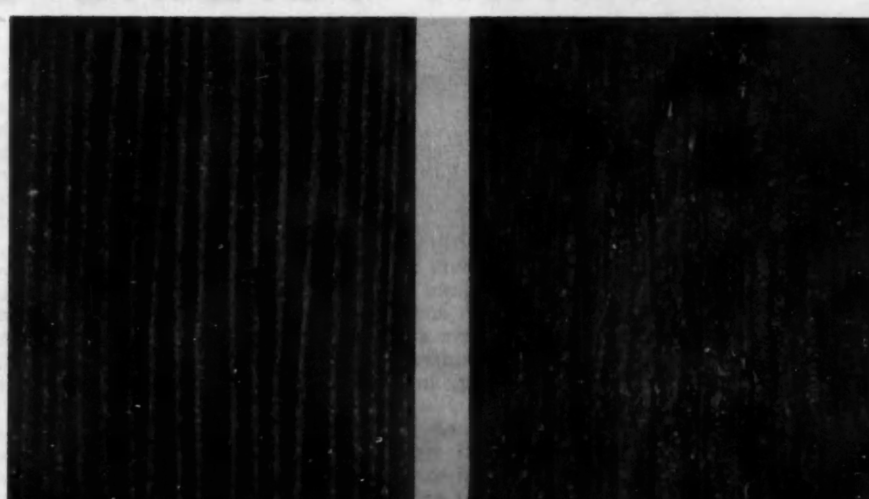
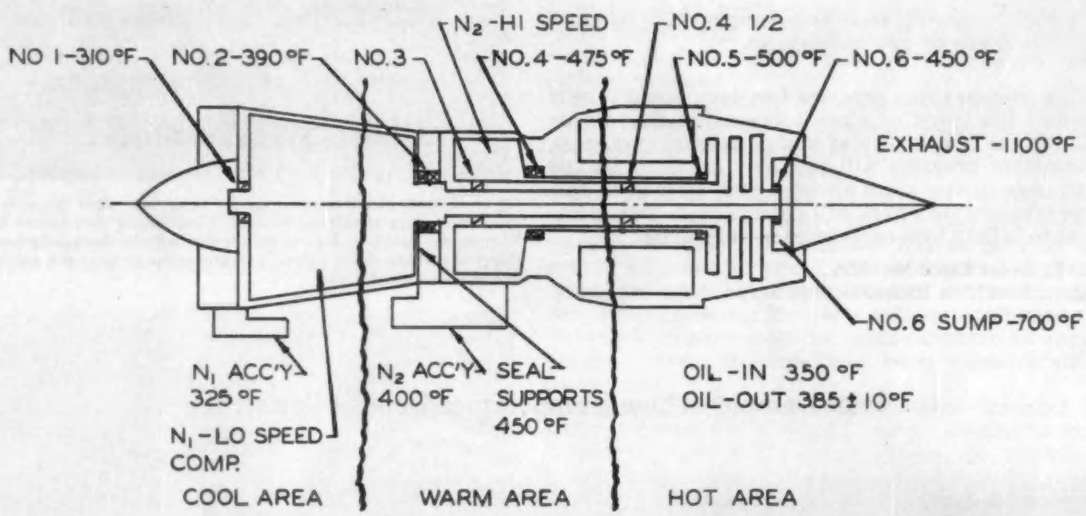


Fig. 6—Two filter cartridges as observed after 10,000-mile low-temperature road test show improvement in current motor oils over those considered premium grade 10 years ago.



TEST ENGINE for the target specification Mil-L-9236, defining an oil of 400 F bulk oil temperature capabilities, is currently the J-57. Oil-in temperature is 350 F. Temperatures of some bearings are close to 500 F. Temperatures average 700 F in the no. 6 sump area, and temperatures as high as 800 F have been measured there. Oil-out temperatures average around 385 F.

Lubricants Keep Pace with Turbine Engines

Excerpts from paper by

Kerry L. Berkey

Propulsion Laboratory
Wright Air Development Center

SYNTHETIC oils for aircraft high-performance gas turbine engines introduced some new problems, but the major ones are the same old headaches which have plagued lubrication engineers for years. That is, thermal and oxidative stability as shown by coke and sludge forming tendencies, load-carrying ability, volatility, foaming, and rubber swell.

A series of screening tests has been developed. They are listed in the synthetic oil specification Mil-L-7808. These tests are designed to determine the aforementioned characteristics of any particular oil before submitting the oil to an engine test. These screening tests are divided into two categories: laboratory or bench tests which determine the physical and chemical properties and rig tests which determine the mechanical capabilities of the oil. If an oil passes these tests, it is then subjected to an engine test which is, of course, our final judge.

To qualify under Mil-L-7808 a test oil is subjected to 300F oil-in temperature (the same as bulk oil temperature), which gives us a 50F pad over service temperatures, and localized hot spots of 700F. The test duration is 100 hr with no oil changes, merely oil additions as required. Engine temperatures to which the oil is exposed range from about 250 to 700F or higher resulting in various types of oil breakdown and deposits. We encounter coke, sludge, and varnish in varying degrees depending on the temperature and the dwell time of the oil

in the area involved. Assuming the test oil completes the engine test, the level and disposition of these deposits determines whether the oil passes the engine test or not.

The qualification of the 7808 oils has entailed a concerted effort on our part. Since early 1954, Wright Air Development Center has screened about 80 oils, of which 21 reached engine testing. Nine were finally qualified. In other words, about a quarter of the oils submitted survived the screening test to get into the engine. Only 9% passed the engine test and were qualified. We have accumulated over 2500 engine test hours in this qualification work.

Generally speaking, our service experience with the 7808 oils has been satisfactory. Storage instability has been our biggest headache. When new, 7808 oils are relatively inert to even the more active engine metals, such as copper, silver, magnesium, and lead. However, upon aging and deterioration in storage, all presently qualified oils will attack the aforementioned metals in varying degrees, particularly lead. We have expended considerable effort in trying to solve the problem. Current thinking is that the deterioration is caused by impurities and tricresyl phosphate or other phosphorus compounds which are used as additives. There appear to be some additives which will prevent this deterioration. Preliminary testing looks promising.

The Air Materiel Command has a storage control program in effect to prevent oils in service from becoming "sour" in storage by using a modified rotating stock plan. Improvement in thermal and oxidative stability is also desirable since prolonged operation in service is occasionally resulting in excessive coke and sludge accumulation.

The load-carrying ability of 7808 oils proved to be marginal for some of the turboprop engines. To correct this condition, a new specification (Mil-L-25336) was introduced defining an oil with a gear-load-carrying ability of 2800 ppi minimum as opposed to the 1700 ppi minimum in Mil-L-7808. To date, we have screened 22 oils, engine tested 5, and qualified one to the new specification. There are no gear problems in the current turbojet engines. Gear loading is at a much lower level in jets than in turboprop engines.

Bearing fatigue is beginning to appear in service and may be a problem within the next few years in the current high-performance engines. Some of these engines have been around for several years now and the bearings are getting some high time on them. This coupled with the high production rate of the engines means more engines flying, which results in more frequent bearing failures. We, along with the whole industry, are studying the problem. Several vacuum melt steels appear to be promising and will help the situation from a metallurgical standpoint. In fact, one of our latest engines may go to an M-50 bearing soon. This steel will permit at least a 250 F increase in allowable rise in bearing temperatures. The present limit is 500F with the 52100 steel now used. We have studies underway to help fatigue from the lubrication

Table 1—Mil-L-9236 Test Lubricants and Results of Engine Tests Run on Them

Oil	Description	350 F Engine Test Results: Test Hours	350 F Engine Test Results: Reason for Termination
A	A mixture of complex esters with oxidation-corrosion and anti-foam additives	53	Excessive number 5 bearing temperature
B	A high-molecular-weight synthetic ester (not a sebacate, azealate, or glycol) suitably inhibited	100	Completed test
C	Similar to lubricant B	100	Completed test
D	A mixture of complete esters with oxidation-corrosion and anti-foam additives	100	Completed test
E	A mixture of 50% polybutene plus 50% heavy neutral mineral oil with pan (phenylalphanaphthylamine)	45	Excessive sludge and coke
F	High-molecular-weight sebacate with a non-conventional oxidation-corrosion additive	70	Excessive viscosity increase
G	Polyglycol plus additives	44	Excessive consumption
H	High-molecular-weight polyester plus conventional additives	65	Excessive viscosity increase
J	A mixture of complex esters with oxidation-corrosion and anti-foam additives	55	Excessive sludge and coke
K	Mineral oil plus conventional additives	20	* Excessive foaming
L	Polybutene plus pan	25	* Excessive consumption
M	Methyl phenyl silicone with no additives	11	* Excessive foaming

* Tests run in same engine.

standpoint, also but have not acquired many data yet.

Since we have covered the bad points of 7808 oils, it is only fair to discuss some of the good points. Consumption is one of the strong points. Our present large engines consume only ½ to 1 lb per hr during normal operation. Another somewhat surprising experience has been our relative lack of elastomer troubles. Several years ago, laboratory studies indicated that we could expect severe elastomer problems. However, no such problems have been encountered. What troubles that have occurred have generally been traced to improper installation of such parts as O-rings, seals, and glands. Even in our high-temperature engine operation at 350F oil-in the elastomers have been no particular problem.

To sum up 7808 oils, we have had our problems, but on the whole these oils have been generally satisfactory. In fact, without these oils, our present first-line aircraft would not be able to fly at the speeds they are achieving.

Now that we have looked at the present state of the art, let us look into the immediate future. For several years we have been working towards an oil which is capable of extended operation at a bulk oil temperature of 400F. The requirement for this oil is staring us in the face today. The latest series of engines will operate on 7808 oils for the time being. However, when the new oil becomes available, chances are that most or all of these engines will switch to the new oil. The next series of engines beyond these will absolutely require the new oils.

In the new engines, not only the higher heat rejection rates of the engines are involved, but ram air temperature rise at the higher Mach numbers comes into the picture. At Mach 1, there is no appreciable rise. Even at Mach 2, we get only 200F rise, which causes no strain. However, at Mach 2.4, we get a 400F rise which is pushing 7897 oils pretty hard. Higher Mach numbers drop 7808 oils right out of the picture. Hence the new program.

Target specification Mil-L-9236 defines an oil of 400F bulk oil temperature capabilities. Most of the major oil companies along with various chemical firms are working on new fluids for this program. Again, we use lab tests, rig tests, and the engine test to determine the suitability of a new oil. Of course, again our final judge is the engine. We are currently using the J-57 engine as our high-temperature engine. We can only go to an oil-in temperature of 350F due to the 52100 steel bearings which are red-lined at 500F.

Some of the bearing temperatures are nudging 500F. There is a 700F temperature in the no. 6 sump area. In fact, we have measured temperatures as high as 800F in this area. Oil-out temperatures average around 385F, which is an accumulated temperature of the return oil from all engine areas. The J-57 engine has done a good job in this testing. We have had no particular problems with the engine.

The nos. 1, 2, 4, 5, and 6 bearings are thermocoupled so we can monitor bearing temperatures during running. We also monitor pressure drop across the engine oil screens, which indicates excessive sludging. A magnetic plug is installed in the oil system. When loose metallic particles contact this plug, a warning light on the operator's instrument panel comes on. In this manner, we can closely observe engine operation and can immediately shut down if trouble occurs. This saves expensive engines from severe failures and, at the same time, permits us to accumulate very valuable engine data. As in 7808 testing, 100 hr is considered a complete engine test.

The 7808 reference engine is also used as the reference engine in 9236 testing. The reference engine is one which was chosen as having the maximum allowable deposits and still be considered as an acceptable engine. We have accumulated about 700 hours at 350F oil-in on the J-57 engine. This involved 12 new oils. Table 1 lists these oils. More complete descriptions cannot be released due to proprietary considerations. Also listed is the duration of the engine test for each oil and the reason for termination of test. As you can see, the test times ranged from 20 to 100 hr. Lubricants B, C, and D completed the full test, with C showing the best overall results. Lubricant A has since been improved and is now considered almost equivalent to C.

Lubricant M is a light silicone which operated in an engine for 11 hr without any overheating of bearings occurring. Bearing temperatures ran up to 50F hotter than the diester oils but were still within limits. We could not operate over several minutes at maximum power due to foaming but were able to get 11 hr at normal rated power, which is equivalent to cruise power. This is the first time we have been successful in operating an engine on a silicone oil. Past attempts failed due to bearing overheating or excessive foaming. The cause of the apparent lack of lubricity in silicones is unknown. There are several theories expounded but none of them has been proved. Considerable study is being expended to determine the cause. The foaming is felt to be a matter of finding a suitable defoaming agent. Work is going on in this area also. With our recent success, the silicone oils are back in the high-temperature lubricant picture.

Aside from the lubricity difficulties with the silicones, the main problem with all the new oils is our old nemesis, thermal and oxidative stability. We have an active program underway at WADC and at several research institutes to develop suitable high-temperature bench and rig tests. None of our present screening tests operates at high enough temperatures to give an accurate determination of oil characteristics at 400F bulk oil temperatures.

We are now running a General Electric J-79 engine at 400F oil-in. If this engine operates satisfactorily at this temperature, we will probably switch our high temperature testing to the J-79 engine. Thus we will have attained our 400F bulk oil temperature plateau and can start serious screening of the numerous candidates available.

As you can see we are getting close to our high-temperature lubricant. When we have at least one good oil, we will revise 9236 and release it as a production version. At that time, qualification testing will start. We are hoping the next couple of months will bring this about.

WADC has been working on the development of oils for the nuclear powerplants. In this program, we have not only the usual lubricating problems but

exposure to nuclear radiation as well. Radiation is proving to be a formidable barrier. None of our current lubricants, synthetic or mineral, exhibits anything resembling satisfactory performance in the presence of radiation. The additives are often the deleterious factor since several base stocks without any additives have looked promising. Most lubrication studies to date have been in the static radiation state: that is, the oil is merely at rest in a container. We have contracts to investigate various fluids in a dynamic condition while exposed to radiation to more nearly simulate actual engine conditions. Our radiation source is 48,000 curies of cobalt 60 with the rigs operating in the source immediate area. Testing is underway and data are being accumulated on a number of radiation-resistant lubricant candidates.

Now to look into the future. As speeds go higher, operating temperatures will rise. Bearing temperatures will go as high as 800F eventually or higher. (Present service bearing temperatures range up to around 375F.) Gear temperatures will rise to at least 600F. (Present service gear temperatures are only at 250F.) Hot spots may eventually reach 1000F or better. Again this is a conservative figure since Mach 4 will give a ram air temperature rise of 1200F (Current engines expose the oil to hot spots as high as 800F.)

All of this along with increased engine powers adds up to higher heat rejection rates. Heat rejection rates are expected to go to and probably will exceed 7000 Btu/min. (Rates of 3000 are about tops at present.) With the rising ram air temperatures and heat rejection rates, naturally bulk oil temperatures will increase also, exceeding 600F. (Present service temperatures are at about 250 maximum, although we are doing some experimental operation at 400F.) Our present estimation is that 600F is about as high as we will be able to go with conventional liquid circulating lubricants. We may not be able to go even that high. Beyond that temperature, some other lubricating scheme must be developed. Work is being done in this area.

To Order Paper No. 47B . . .
. . . on which this article is based, turn to page 5.

Oil Consumption . . .

. . . in passenger cars can be predicted by measuring the equilibrium used oil viscosity at 210 F. Method is applicable to a wide variety of oils.

Based on paper by **J. K. Patterson and R. C. Gregor** Esso Research and Engineering Co.

EQUILIBRIUM used oil viscosity at 210 F has been found to be a logarithmic function of substantially the same form for cars of high or low oil consumption. This makes possible laboratory prediction of the consumption characteristics of finished oils of widely differing viscosity indexes. Here is how the method was developed:

At the beginning of each driving period, the crankcase of each car was flushed and charged with the test oil. All visible leaks were eliminated. The cars were then driven in routine passenger-car service by the owner for periods of 5–6 weeks without oil drains, averaging about 1200 miles each period. Oil additions and drainings were measured by weight. Either regular or premium gasoline was used, depending on the habits of the owner.

Statistical correlation methods were applied to the test data to determine the best method of describing the effect of viscosity on oil consumption. A logarithmic relation between the oil consumption and the equilibrium used oil viscosity (as removed from the engine at the end of the test period and including dilution) at 210 F was found to describe the data best. This relationship is shown graphically by the dark circles in Fig. 1. Both linear and logarithmic relations of the new oil viscosities and the equilibrium used oil viscosities at various temperatures between 100 F and 300 F were fitted to the data. The results of these analyses are shown in Fig. 2. In this figure, the coefficient of determination (R^2) represents the fraction of the total variability in the oil consumption that is accounted for by the method of correlation. Values of R^2 as low as 0.4 can be considered significant. The 0.97 value obtained for the logarithmic equilibrium used oil viscosities at 210 F represents a very high degree of correlation.

The test design was such that it was possible to separate the high-consumption and low-consumption cars. The oil consumption values for the 13 high-consumption and the 13 low-consumption cars are shown as open circles in Fig. 1, compared with the over-all averages (dark circles). The random scatter around the correlation lines is somewhat greater than for the overall averages since fewer cars are involved. Nevertheless, a similar relationship appears to hold regardless of oil consumption level.

This empirical relationship can be expressed by means of an equation of the following form:

$$Q = B\,(U_{210})^{a}$$

where:

Q = Oil consumption, qt/1000 miles

U_{210} = Equilibrium used oil viscosity, SUS at 210 F

a and B = Constants determined by data

The value of B is relatively unimportant. It

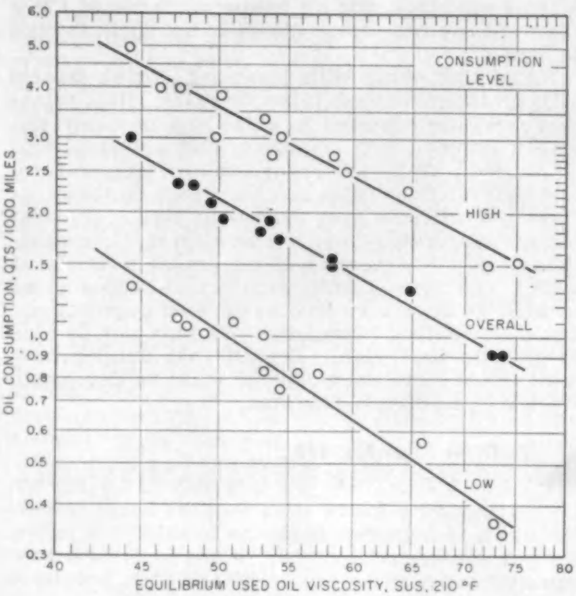


Fig. 1—Logarithmic relation between oil consumption and equilibrium used oil viscosity at 210 F is shown graphically by the dark circles.

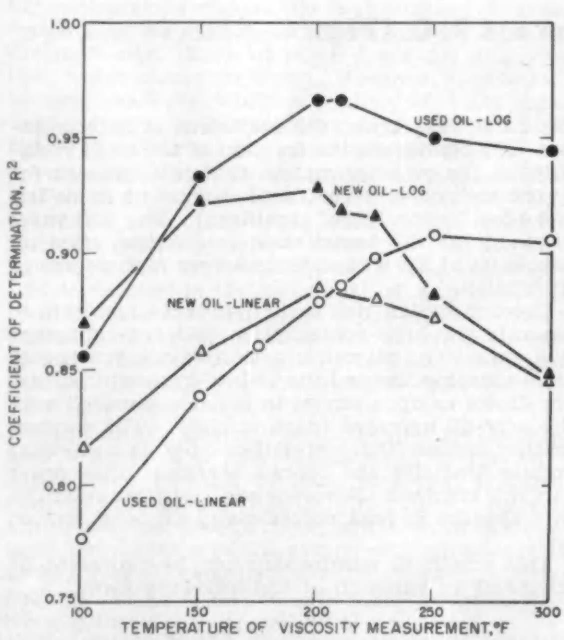


Fig. 2—Linear and logarithmic relations of new oil viscosities and equilibrium used oil viscosities at temperatures between 100 and 300 F. The 0.97 value for logarithmic equilibrium used oil viscosities at 210 F represents a high degree of correlation.

Table 1—Viscosity Dependence Constant

	Average Oil Consumption, qt/1000 miles	a
Low Consumption (13 Cars)	0.86	−2.7
High Consumption (13 Cars)	3.03	−2.1
Average (39 Cars)	1.82	−2.2

merely describes the oil consumption level, which can better be described by the average oil consumption of the group. The constant a, however, is a measure of the viscosity dependence of the oil consumption of the various groups. The values of a for the data from this test are shown in Table 1.

While these values may indicate a somewhat greater viscosity dependence for the low oil-consuming cars (which could be due to the difference in distribution of car types in the subgroups), the difference between the high and low oil-consuming cars is probably within the reproducibility of the data.

The major factors which determine the equilibrium used oil viscosity are dilution and V.I. improver breakdown. The amount of fuel dilution was found to be substantially independent of the oil type, averaging about 3%. But the viscosity loss due to this dilution was greater for the heavier oils. It was also found that cars operating on premium fuels averaged one-third less dilution than those operating on regular-grade fuel.

The viscosity loss due to permanent breakdown of the V.I. improver depends primarily on the amount and type of improver (how much viscosity it contributes and its shear breakdown characteristics). The high breakdown V.I. improvers lost between 40 and 50% of the viscosity they contributed, while the low breakdown ones lost between 20 and 35%. There may be a tendency for a lower percentage loss when the contribution is low and it is probable that this is due to the difficulty of measuring these small differences.

From the foregoing one can predict the consumption characteristics of an oil if the new oil viscosity and amount and type of V.I. improver are known. The anticipated equilibrium used oil viscosity is determined by subtracting the loss due to the V.I. improver breakdown and that due to dilution from the new oil viscosity; the oil consumption under typical service conditions can then be determined from Fig. 1.

If the amount and type of V.I. improver are not known, or if the improver breakdown characteristics are unknown, it is still possible to estimate the equilibrium used oil viscosity by means of sonic shear apparatus.

Other field test results have indicated some average value between the new and equilibrium used oil viscosity may be even more precise in predicting oil consumption, also that the volatility may have importance in determining oil consumption.

To Order Paper No. 252 . . .
. . . on which this article is based, turn to page 5.

Ryan Vertiplane

. . . is a high-strength, light-weight aircraft using the deflected slipstream principle to achieve vertical lift.

By **Burt Winslow,** Ryan Aeronautical Co.

Developed for the Army, under technical direction of the Office of Naval Research, the Ryan "Vertiplane" (Model 92) operates in the conventional, horizontal attitude in all phases of flight, including take-off, landing, and both vertical and horizontal flight.

The Model 92 is a two-place, single-engined aircraft, using two propellers which are powered by a Lycoming T-53 gas turbine located within the fuselage. Because it is a research airplane, designed to explore a new realm of flight, its weight/horsepower ratio was kept to a minimum. For instance, while helicopters are designed to an empty weight of 5 lb/hp, the Vertiplane, with an 825 shp gas turbine has an all-up weight of about 2600 lb, or slightly more than just 3 lb/hp.

The Vertiplane's engine is mounted in the fuselage with a special gearbox which reduces shaft speed, splits the power, and directs it to a pod-mounted gearbox and propeller on each wing. The shaft between the main gearbox and propeller gearbox is fully exposed with a barrel spline on each end to correct misalignment due to wing deflection. A vibration damper is located about two-fifths of the length of the shaft from the fuselage, to prevent the small-diameter shaft from whipping.

The engine is fitted with a bellmouth, and draws its primary air from a plenum chamber. The air is admitted to the plenum chamber by means of a perforated door located on top of the fuselage.

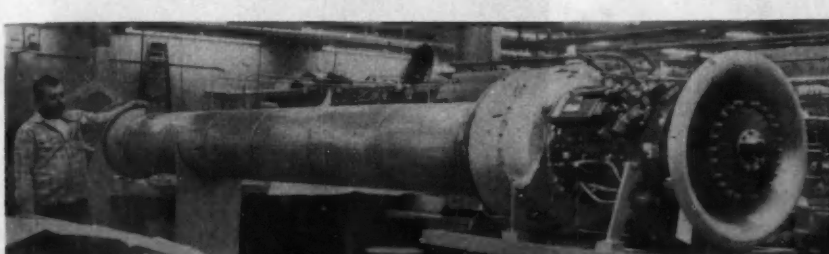
A combination fuel and oil tank is located just forward of the engine, high enough to permit operation without a fuel boost pump. The tank has a narrow vented and drained air space, to prevent the fuel and oil from contaminating each other and to detect any leakage.

The engine is supported with the conventional trunnion mounts with a third point for a steady rest. Because the engine is of reverse-flow type, the necessity for shrouding is eliminated. The firewall is made of 0.002-in. SAE 30321 corrosion-resistant (stainless steel) sheet spotwelded to a corrugated sheet of the same material.

The air for cooling the aft section of the fuselage is scooped in at the bottom of the fuselage, between the flaps. This arrangement provides flow of air even when the airplane is hovering.

The tailpipe is also made of 0.002-in. SAE 30321 sheet which is spotwelded to a corrugated sheet of the same material. The corrugated sheet is on the exterior with the corrugations extending lengthwise down the entire length of the tailpipe. Diameter of the tailpipe, which is 14 in., is maintained by flanges at the front and rear and intermediate rings. The front flange is designed to receive a Marmon clamp, which fastens the tailpipe to the engine. The rear flange acts as a cylinder wall for a piston-type sealing ring. An insulating blanket, which actually weighs more than the tailpipe itself,

To learn more about vertical take-off and landing aircraft, Ryan has built the Model 92 research Vertiplane. Vertical lift is achieved by deflecting the propeller slipstream.



Tailpipe assembly used with the Lycoming T-53 gas turbine engine is made of stainless steel sheet spotwelded to a corrugated sheet of the same material. Outer corrugated sheet is visible here.

is wrapped around the assembly to protect the aft end of the fuselage.

The tailpipe assembly is an example of fabricated light-weight, high-temperature structure. It involves new Ryan techniques for spotwelding very thin gauge corrosion-resistant steels while maintaining high structural properties.

The nozzle, which is designed as a separate unit, is rigidly attached to the fuselage, thus supporting and allowing the tailpipe to expand into it. The nozzle incorporates a movable, conical plug which can deflect the jetstream at right angles, through a circumferential slot, to eliminate all forward thrust. A fully-gimballed cover is added to the nozzle and connected to the rudder and elevator systems. Pitch and yaw control is achieved, when the Vertiplane is hovering, by shielding one side of the nozzle and forcing the jetstream out the opposite side.

To achieve roll control, the propeller pitch control is connected to the control stick in such a way that, when the flaps are extended, the ailerons actuate the propeller pitch control. This permits differential pitch control between the propellers under hovering flight conditions, while still maintaining uniform pitch control for normal flight.

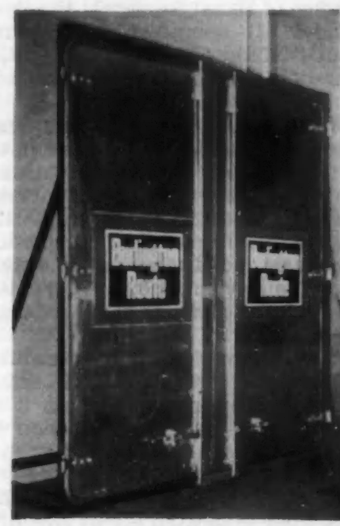
Homemade Tools For Fleet Shops . . .

. . . save capital and maintenance costs

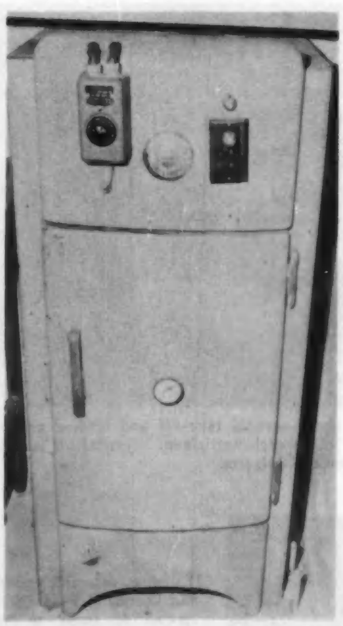
Based on discussion by

J. H. Dolan Burlington Truck Lines, Inc.

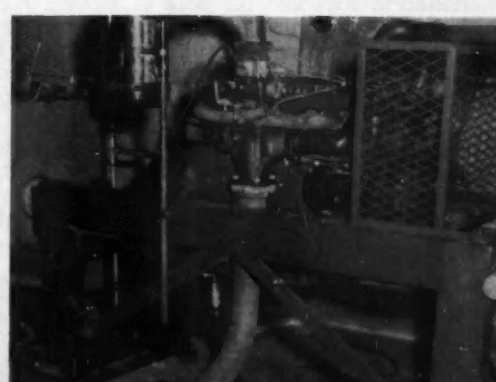
presented at a Round Table on Shop Tools in Fleet Maintenance.



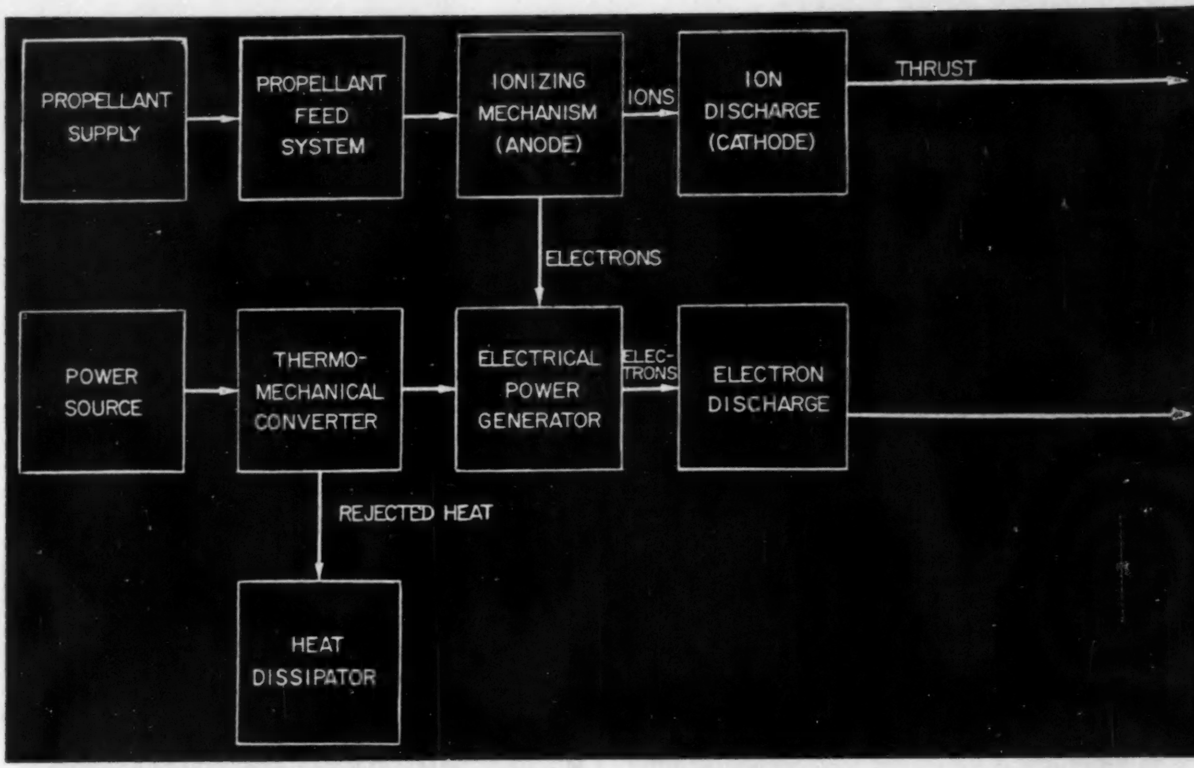
Trailer Door Jig—Doors can be built up in the shop with all hardware attached. Large trailers or trucks do not tie up shop space during repairs. Approximate cost —$180.00



Piston Bearing Heater—Even heat is applied by infra-red lamps within the cabinet. No bearing distortion results. Savings in time per set—$2-3. Approximate cost—$38.



Engine Dynamometer Stand—Homemade stand is more flexible than commercial models since it can be moved around the shop. Approximate saving in original price—$825. Approximate cost—$1350.



THIS ION ROCKET ENGINE MODEL is the one upon which the analysis is predicated. Propellant is carried in a convenient form, solid, liquid, or gas, in a supply system. In its passage through the feed system it is vaporized and then introduced into the ionizing chamber at a controlled rate. The ionizing mechanism is an electric arc or heated metallic plate, for example one of tungsten or platinum.

The body of the ionizing chamber collects the electrons, and they in turn pass through the electrical power generator. The ions are extracted from the ionizing chamber by an electrostatic field and accelerated to a suitable velocity to produce the major component of thrust from the rocket engine. The electrons after passing through the generator are reproduced by thermionic emission. They, in turn, are accelerated by a second electrostatic field of a strength sufficient to bring the electron velocity to approximately that of the ions.

According to a theoretical investigation

The Ion Rocket Engine Can Produce Usable Thrust

Excerpts from paper by

R. H. Boden

Rocketdyne Engineering, North American Aviation, Inc.

THE ion rocket engine in which the propelling ions are accelerated by an electrostatic field has the capability of producing usable thrust levels. It may be used to supplement other rocket engines in applications to space vehicles.

These are the conclusions of a theoretical investigation of the ion rocket engine carried out in 1957 at Rocketdyne under the sponsorship of the Directorate of Advanced Studies of the Air Force Office of Scientific Research. The ion rocket ejects both ions and electrons in order to maintain an electrically neutral vehicle. Both are ejected in a direction opposite and parallel to the direction of thrust. The ion may be an atom stripped of one or more electrons or it may be a submolecular or molecular species or combinations of several atoms.

If the relative velocity of the ions and electrons is

large, the probability of their recombination on the formation of a neutral plasma is small. It is believed that the ion and electron velocities should be of nearly the same magnitude and that more electrons than ions should be ejected in order to give the vehicle a slight positive surface charge.

The results of the study program conclusively show that three major problem areas exist in the development of the ion rocket engine. These are the ion thrust chamber, the propellants, and the development of a high specific power generator. These three areas apply to electrical propulsion systems in general.

The ion propulsion research program is to continue for the coming year at Rocketdyne under the sponsorship of the Directorate of Advanced Studies, AFOSR. In addition to the theoretical work a limited experimental program is to be performed.

The theoretical investigation showed that:

- Three parameters, the ratio of the accelerating voltage to the effective atomic or molecular weight of the propellant per unit charge, the gross weight of the vehicle, and the thrust-to-weight ratio, determine the design characteristics of the ion rocket engine.
- The maximum thrust-to-weight ratio to be expected from an ion rocket engine using presently available power generators is less than 10^{-4}.
- Propellants of the highest possible atomic or molecular weight which form singly charged ions are most efficient for use in the ion rocket engine.
- Power is wasted if light-weight ions or electrons are used to develop thrust.
- Ions having atomic or effective molecular weights of less than 100 gm produce thrusts too low to be of use.
- The major problem of the ion-propelled space vehicle is the continuous development of high specific power.
- The Linac linear accelerator, which uses a radiofrequency resonant cavity to achieve extremely high ion velocities, is impractical for application as an ion thrust chamber.
- The ion thrust chamber is basically a simple device consisting of an ion source with an accelerating electrode, and an electron source also with an accelerating electrode.
- Productive avenues of research, directed toward achieving a successful high-thrust ion rocket engine, are high-specific-power electrical generators and heavy ion propellants.
- The design of the thrust chamber demands a compromise judgment in the selection of the accelerating voltage, the propellant, and the thrust-to-weight ratio of the vehicle to achieve the optimum balance among specific power demands, size, weight, and operating time of the rocket engine.
- The minimum accelerating voltage for an ion thrust chamber is now estimated to be 12,000 v.

Mathematical basis for these statements is contained in paper No. 41D.

To Order Paper No. 41D . . .
. . . on which this article is based, turn to page 5.

Tomorrow's

Based on talk by

A. A. Kucher

Ford Motor Co.

BASIC and applied research have ceased to be necessary evils.

Our modern research laboratories are equipped with the finest instruments and equipment. And these laboratories are staffed with competent scientists and engineers who devote themselves with great objectivity to basic and applied problems having major impact on future materials, processes, and devices.

No longer do our research engineers have to drop their developments in midstream to help put out production fires. Basic research has successfully established isolation in the midst of activity. We have evolved a process of continuity of effort from concept to the end product. We are now in a position to take advantage of procedures vital to the fulfillment of the staggering demands of the future.

Production's Future

We must develop means whereby tolerances can be shrunk economically to the vanishing point.

Precision today is limited by attainable dimensional tolerances. Over the years, these tolerances have been reduced from fractions of an inch to thousandths and to hundred thousandths.

With each succeeding reduction in tolerance, the quality and functional uniformity of the end product has been improved.

Today's tolerances limit us in many cases to selective fits or wide variations in function. If we stack up all the go's against all the no-go's of a given assembly, we find a wide disparity in uniformity of function.

Since tool wear is largely responsible for the necessity for tolerance and also the determining factor on the number of pieces that can be machined within an allowable tolerance, it follows that cutting tools

Production

Here's a hint of what the future holds for production in the way of tooling, materials and engineering.

having nearly infinite life will eliminate downtime and other costs incident to tool change.

Tool wear, however, is only one of the controlling factors in maintaining tolerances. Bearing and spindle wear are of almost equal importance. Therefore, better bearing materials and lubricants will contribute to uninterrupted processing.

Also, since time, whether during operation or during transfer of parts through operations, determines the piece part cost, it is mandatory that the transfer time between operations be reduced to a minimum.

Along with improvements in tool life, bearing life, and transfer time will come substantial increases in cutting feeds and speeds.

In addition, precision is dependent upon environmental temperature control if measurement is to be controlled in Angstrom units rather than hundred thousandths.

Electronic sensing and feedback systems will instantly correct deviations in processes and dimensional variation so that rejections and scrap will reach the vanishing point.

In time, many presently complex single-structure machines will give way to assemblies of units. The cutting heads will be standardized to a greater degree, as will transfer and handling devices. Measurement and inspection units will be inserted as required. Power systems, such as hydraulic units, will be easily adaptable and readily inserted, as electric motors are today. Programming and control elements will be built up from a series of plug-in subassemblies, and programming will be controllable by memory (or information storage) devices. The improved flexibility in setting up varied sequential operations as well as the replaceability of components will reduce obsolescence.

The broader use of locating lugs for holding parts during the entire chain of operations will contribute to greater accuracy.

Precision will be applied in the processes which precede machining. Shell molding, precision forging, and die casting will reduce the amount of material to be removed. In the foundries, the use of precision machine molding, automated mold assembly and transfer, and continuous metal pouring will be completely developed.

Further, many of the processes for cutting materials will give way to chipless machining. Extrusion forming, roll forming, die forming, and other pressure forming means will result in reduced tolerances, and improved surface finish and surface hardness.

The future of inorganic materials will be limited largely to four metallic elements—iron, aluminum, magnesium, and titanium—and one semimetal—silicon—for major construction. The other elements are becoming scarcer and therefore too costly for use even as alloying agents. Ceramic and ceramic metal compounds capable of undreamed properties will be commonplace.

Scientists will have learned much about the structure of matter and will be able to engineer materials, from these common elements, to suit one's needs. It will no longer be necessary to compromise systems to materials. This will affect production equipment as markedly as it will the product itself. The production engineer will have cutting and forming tools made of materials compounded to his prescription and precisely suited to the job at hand.

The development of the continuous flow process is a phenomenon which applies to engineering just as well as it does to production. The explosion of all technology and the imperative need for progress calls for a stepped-up rate of achievement. This will be accomplished by the intimate collaboration of the scientist, the product design engineer, the production engineer, and the supporting activities. The flow of a concept from the basic research phase to production is accelerating. Not long ago, two generations was not an unusual period for this transition. Today, we have reduced the span to ten years or so. In the future, the complete integration of the basic sciences in the process of development will enable us to reduce the time to a true minimum.

Leakage and materials are the problems to lick in producing a

1000 F Pneumatic Servo System

Based on report by

C. H. Cannon,

Lockheed Aircraft Corp.

Based on report to SAE Committee A-6, Aircraft Hydraulic and Pneumatic Equipment

1000 F, 5000 psi, and 500 hr life are Lockheed's design goals for a pneumatic system mockup to operate the dive brakes of a supersonic airplane. The Georgia Division is testing materials and designs under true simulated flight conditions.

Three adjacent compartments house the power generating, transmission, and power actuating components of the system. Each section is individually heated and cooled to simulate flight profiles.

Generating the Compressed Air

The generating section contains the air compressor and a flame arrester. The airborne compressor is not included in our development and will be handled separately. The compressor pressure will be 5000 psi and the demand will be 3.75 lb per min at sea level with 75 psia inlet pressure. In the early system tests we will use a commercial compressor located outside the compartment. We have a 6000 psi Chicago Pneumatic compressor that delivers 12 lb of air a min. With the exception of the compressor, all other components of the system are airborne.

Piping the Air

Leaving the first compartment the air is carried through lines to components in the second compartment. The air traverses through them in this order: filter, relief valve, moisture separator, chemical drier, back pressure valve, check valve, reservvoir and pressure switch, pressure regulator, another relief valve, pressure transmitter, shut-off valve, and finally another filter.

Operating the Dive Brakes

Leaving this compartment the air now enters the power actuating compartment. The air is transmitted through lines to the servo valves and into the power cylinders. The servo valves will be actuated by automatic cycling equipment located outside the test compartment. The power cylinder loads are resisted by torsion bars, also located outside the compartment.

The power actuating units comprise two separate power cylinders, one for each dive brake door. The doors are actually fuselage-mounted, one on each side of the airplane. On the mockup, torsion loading bars are employed to simulate the hinge moment loading of the doors. The extremely high loads and rigid operating requirements dictate a good test for the pneumatic servo. Each power cylinder must be capable of operation under high axial load and extremely fast rate of travel. Manual input control to the servo valves and two units are synchronized by interconnection of the valve inputs.

Although most dive brake controls are operated by electric valves, the purpose of using a manual input was to provide a system similar to flight controls such as elevator or aileron control. We are developing an electric-pneumatic valve and control because most missiles require electric inputs and

future aircraft will use autopilots and stability augmentors requiring electric inputs.

Wanted!—High-Temperature Materials

We talk about a pneumatic *system*, but our major effort so far has been on *materials* problems. The first problems are metallurgical ones. We realized that 5000 psi, 1000 F components were not available but we did expect to find more information on high-temperature materials. The aircraft-engine manufacturers have been the best source of information for materials at 1000 F. However, in compressor sections of engines no metal-to-metal contact is used and clearances are used to prevent galling and seizing. Tail pipes encounter high temperatures but no mechanical motion. In our power actuator and servo valve we must have metal-to-metal contact for keeping leakage low and so seizing and galling must be prevented.

Until you actually calculate leakage on a specific unit you cannot realize the problem. At first we believed we could tolerate leakages by rod seals, gland seals, and through the servo valve. However, on a servo valve and actuator combination for aircraft flight controls, this leakage must be held extremely low, due to the number of servos used. Say we tolerate 0.05 lb per min leakage per valve. This compounds by 8 to 0.40 lb per min if we use dual valves and place two for elevator, two for rudder, and two at each aileron. At high altitudes compressor output becomes critical and it would require a huge compressor just to make up leakage. Also, where pneumatic servos are used in missiles the applications may employ stored air in reservoirs and naturally leakage must be held to a minimum to prevent excessively large storage containers.

One of the metallurgical problems then is to find proper finishes or processes to prevent seizing, galling, or excessive friction of the high-temperature alloys. Our power cylinder will have an Inconel-X barrel with provisions for a liner of Stellite No. 6B. The piston head is Inconel-X and is designed so that several surface treatments such as flame plating may be evaluated.

The pistons are also adaptable to many types of seal configurations. The end glands of the cylinder are designed to accomodate several seal configurations. We have found many seals that have been developed for high temperature, mostly metallic. Some of these are Koppers carbon-graphite seals, Johns-Manville Cumpac rod seals, Precision Ring Stellite rod and piston seals, Skinner carbon-graphite seals, and Waldorf Instruments self-energizing seal.

We have conducted tests on various metals in a Modified MacMillan Wear Tester to evaluate metal-to-metal properties. We have experimented on Inconel-X, Stellite, A-286, and other basic materials with finishes such as flame plating, nitriding, hard chrome plate, Malcomizing, and chromizing. It is hoped that the surface hardness of Inconel-X may be increased from 35 RC to in the neighborhood of 50 RC by one of these methods.

Dry Lubricants Used for 1000 F Temperatures

Dry-film lubricants are the only possibility at 1000 F. Currently under test are: Electrofilm No. 1000 and No. 2006, Acheson Colloids No. DJ601, Drilube No. 700, and Everlube, High-Temperature Type. Gas lubricants, or a mixture of lubricants suspended in a gas surrounding the parts, are undesirable because of the amounts necessary for an airplane mission. Molybdenum disulfides and powdered graphites do not appear at present to be a solution.

Designing the Pneumatic Servo

The majority of our analytical work has been on the pneumatic servo. We have also tested a pneumatic servo using a spool valve and power cylinder which operated in a mockup of the C-130 rudder system. The power medium was bottled nitrogen with pressures varying from 600 to 2100 psi. The output mass was varied from 0.27 to 1.20 lb-sec^2 per in. and the output spring rate was 14,000 lb per in. The frequency response was approximately five cps and the system was stable through a wide range of variation in system parameters.

The original valve spool had 0.0005 diametral clearance and leakage was approximately 2.0 lb per min. This servo was stable. However, the leakage was unacceptable. The valve spool was replaced with a new one machined to 0.000050 diametral clearance. This reduced the leakage to 0.04 lb per min on one valve and 0.08 lb per min on another. The discrepancy was in the clearance but how do you measure to check 50 millionths clearance. All dimensions were checked with a Talyrond gage. With a valve of these tolerances the engineer naturally worries about contamination and deflections inducing valve seizure. We are concentrating on these areas and have designed valves with sharp edge spools to shear any contaminant. Very heavy bodies are used to prevent distortion when valves are bolted to the actuator and pressure forces are working on the valve.

In the original valve and all valves to date, valve damping is required. In these valves 85% of the 4000 psi supply pressure is metered to each side of the power actuator at neutral to maintain stiffness of the output loop. The bulk modulus of the trapped air is about 3500 psi at 1000 F. This value is very low; however, at 1000 F any hydraulic fluid extrapolated to this temperature will be comparable.

To compensate for this low output spring rate the servo valve must pulse at high frequencies to counteract any disturbance produced by aerodynamic forces. In other words the surface is susceptible to flutter or buzz by aerodynamic forces and, in order to prevent this, a high spring rate or a stiff output is necessary. The low bulk modulus at 1000 F is a deterrent; however, with the medium of air this bulk modulus is fairly constant from ranges of 0 F to 1000 F and the servo can be designed for the known and fixed value. With a variation in bulk modulus for hydraulic fluid, designing for stability over the complete range is almost impossible. For instance, at 100 F bulk modulus of OS-45 is 220,000 psi and extrapolated to 1000 F is 8000 psi. This value is for a quiescent cylinder pressure of 2000 psi or 66% of 3000 psi supply pressure. The tremendous bulk modulus decay seriously impairs the hydraulic servo. Even at 600 F the bulk modulus of OS-45 Type III is 68,000 psi contrasted to 240,000 psi at standard day temperature. The constant bulk modulus characteristics of air over the temperature range does give the pneumatic servo the advantage.

European Production Methods

– ANOTHER SPUTNIK?

"WE COULD be out-Sputniked in more than one area."

This warning was solemnly expressed by one participant on an SAE Foreign Production Methods Panel at Detroit against complacency and failure by U. S. production executives to appreciate the tremendous strides in manufacturing being made by European automobile producers.

Here are some facts about European automobile production that took many in the audience by surprise.

- Daily production rates in many European plants *today* exceed 1,000 vehicles. Fiat is building 1,500 cars per day. Both Renault and Fiat expect to reach 2,000 cars per day in less than 2 years.

- Passenger car production during 1956 in Great Britain, Germany, France, and Italy totaled 2,564,275 units. This is about three times the prewar output and nearly 11 times the postwar year of 1946.

- The new Vauxhall plant has installed what may be the first equipment to spray cellulose lacquer with automatic contour machines.

- European machine tools are equal, and some undoubtedly surpass, U. S.-built machine tools.

- A German firm has developed an interesting new method of dip-polishing. The method is used for irregular shapes, including hubcaps, door handles, and similar hardware.

- Precision forging and automatic cycling of the forging process have been developed to a remarkable degree. One Austrian forging machine for solid stock or tubing presets cycles for as many as 7 diameters and variable lengths.

- A panelist described the recent Tool Machine Show at Hannover as "The most fabulous display of machines I have ever seen." It certainly outclassed, he said, our own Chicago Show.

- Europeans have many fresh designs for large machine tools. This applies particularly to boring mills, planers, and planer type mills.

- Top executives of European firms pride themselves in the fact that they are aware of details. They also pride themselves on "having time for details."

- Europeans are doing a remarkable job of building versatility into their latest equipment.

- Volume output of European accessory manufacturers today is impressive. An English manufacturer produces 7,000 automotive generators, 7,000 starters, and 50,000 lamp assemblies per day.

- Europeans have contrived many ingenious production arrangements. In some installations, 4 or

AMERICA'S MILITARY SUPREMACY has already been challenged. Do we face a similar challenge on the production front?

Will advanced European manufacturing techniques—plus Europe's traditionally low wages and liberal apprentice programs—pose the most serious threat yet to America's economic position?

Too often, it has been suggested, U. S. production executives are so busy telling our European visitors what we are doing over here that we fail to learn from them what is going on in Europe.

Reports by an SAE panel of U. S.-trained production experts who have recently returned from Europe indicate (1) phenomenal progress in production techniques has been made in free Europe during the past decade, (2) Americans have much to learn by studying European manufacturing methods, (3) pooling American know-how with the new European technologies outside the Iron Curtain could trigger some remarkable advances in equipment and processing that would be far ahead of anything we have today.

Serving on the panel were:

panel chairman:
G. R. Fitzgerald, General Motors Corp.

panel secretary:
Howard Roat, General Motors Corp.

panel members:
E. F. Gibian, Thompson Products, Inc.

Harold Johnson, Vauxhall Motors, Ltd.

P. A. Miller, Ford Motor Co.

S. K. Rudorf, A. O. Smith Corp.

The program, sponsored by the SAE Production Activity, was organized by C. W. Ohly, Membership Vice-Chairman.

5 punch presses are tied in with an assembly operation and the assembler operates the presses.

- In Europe it is not unusual to see an apprentice school for toolmakers with 50 apprentices from 13 to 14 years of age. Apprenticeship is not necessarily limited to male apprentices.

Discussion brought out the fact that passenger car and truck output for 1946 by England, Germany, France, and Italy was only 473,671 units. By 1950, vehicle output reached 1,556,123. Five years later production had increased to 3,138,540 cars and trucks. 1956 output was slightly higher and 1957 production may be the highest on record despite the Suez crisis which resulted in gasoline rationing in most European countries and extended into the first few months of 1957.

GM's Vauxhall production during 1957 was about 150,000 vehicles, even though two new cars were introduced and a new plant was put in operation.

The Opel plant with 9,000,000 sq ft now employs 30,000. Capacity is 250,000 units per year. 1957 production was approximately 230,000 vehicles.

A European plant is installing a final assembly line which is practically completely automated as far as handling of components is concerned. There is a possibility this line will eventually operate from a punched card procedure.

It is possible to buy in Europe today machine tools and equipment that are equal to any being made in America. Most European technicians have spent considerable time in U. S. observing equipment and production methods. Many things they have seen have been duplicated; others have been improved upon.

The European industry can teach us many things, it was suggested.

The point was also brought out that there has been widespread adoption in Europe of U. S. production methods. During 1957, American visitors reported seeing a steady stream of U. S.-built machine tools being unloaded. They also reported seeing many manufacturing installations that were impressive.

These installations were mentioned specifically: (1) Simca's new and modern paint shop, (2) an unusual underground forge shop conveyor system used by Simca and Renault, (3) Fiat's very impressive assembly line (probably equal to any U. S. line), (4) extensive use of large T-lathes with copying attachments, (5) new and interesting approaches to airfoil machining by Sicomatic in Switzerland.

U. S. firms are reported to be trying the new Ger-

German Car and Truck Production

	1938	1946	1950	1955	1956
Volkswagen	—	9,931	90,558	329,983	395,690
Opel	140,580	839	72,746	185,340	207,010
Daimler-Benz	33,949	2,231	42,305	89,162	104,311
Ford-Taunus	24,443	4,649	29,816	80,376	86,146
Totals	198,972	17,650	235,425	684,861	793,157

British Car and Truck Production

	1938	1946	1950	1955	1956
Vauxhall Motors Ltd.					
Commercial Vehicles	25,239	33,361	40,783	67,698	63,276
Passenger Cars	32,749	15,599	47,692	75,323	64,595
Totals	57,988	48,960	88,475	143,021	127,871

British Motors Corp. — 1957 Production 450,000 vehicles (33% greater than 1956. 49% of production exported. 59,000 vehicles exported to U. S.).

Ford Motor Co., Ltd. — 1957 production 343,000 vehicles (54% of total production exported. 23,000 vehicles exported to U. S.)

French Car and Truck Production

	1938	1946	1950	1955	1956
Renault	49,552	28,836	133,916	221,785	261,860
Citroen	65,432	24,445	81,768	181,824	190,903
Ford-Simca	N.A.	16,665	51,874	158,604	179,084
Peugeot	47,368	13,768	62,484	124,740	141,616
Totals		83,714	330,042	686,953	773,463

European Car and Truck Production

	1938	1946	1950	1955	1956
Great Britain	437,718	327,760	785,217	1,240,912	1,006,756
Germany	318,284	20,836	285,472	903,789	1,069,283
France	215,906	96,092	357,587	725,083	827,048
Italy	62,682	28,983	127,847	268,756	309,390
Totals	1,034,590	473,671	1,556,123	3,138,540	3,212,477

European Passenger Car Production

	1938	1946	1950	1955	1956
Great Britain	345,202	184,373	522,515	904,725	708,306
Germany	261,767	9,925	216,122	761,474	908,043
France	191,394	30,429	257,289	581,994	674,616
Italy	56,014	10,989	101,310	230,833	273,310
Totals	854,377	235,716	1,097,236	2,479,026	2,564,275

European Production Methods

- ANOTHER SPUTNIK? continued

man dip polishing process on aircraft valves, jet engine blades, and impeller wheels.

In addition to use of the Sejournet forging method employing a glass lubricant, there was a report of a GFM machine at Steyr, Austria, which forges solids or tubing using preset cycles for as many as 7 diameters and variable lengths. Closing of dies, speeds, and feeds are push-button controlled and preset.

Another GFM horizontal-type forging machine for rocker arms used controlled feeds at two forging stations in line for blocking and finishing.

A third GFM machine developed for jet engine blades has two horizontally opposed forging dies that move through a 90 deg arc. An automatic cycle controls feed, hammer closing, and amount of die rotation. The fact was emphasized that European manufacturers have "beefed" up their machines substantially, although hardened ways are not as common place as they are in the United States. "We wouldn't need hardened ways if we didn't insist on using shoemakers to run our tools," a Swiss gentleman told a U. S. visitor.

There is much cross-breeding of U. S. and European machine tools. Many U. S. machine tool builders are negotiating cross-licensing agreements, it was indicated.

One speaker said he did not see any high production equipment associated with automobile manufacturing which surpassed American equipment.

We appear to be holding our own in numerical controls, he believes.

He also reported seeing "some impressive Keller-type duplicating equipment which was said to be faster and more versatile than ours."

The top machine tool people in Europe are invariably people with solid engineering backgrounds, it was indicated. All management-type people are intimately familiar with details of their machines, including the choice of bearing materials.

A Frenchman, head of a large machine tool firm made this interesting comment about up-and-coming young men in industry today: "They all want to charge out and slay dragons—no one wants to get to work picking the fleas off our dogs."

Europeans are making considerable use of optical read-out stations. They have made impressive progress in cutter grinder equipment. Some of their equipment—particularly tool room equipment—is more versatile than ours.

Impressive progress has been made in spark gap metal disintegrating. A participant reported seeing a machine sinking a forging die from the solid. The electro-eroded area was approximately 7 × 14 in.

There is much emphasis in Europe on copy turning. Ceramic tools seem to be in about the same state of development as here in America.

Panel speakers see a promising future ahead for pooling European and U. S. production know-how. "A cross-breed of German inventiveness and meticulous engineering, Swiss precision, the electronic skills of the British, the refreshingly new concepts of the Italians, and our own industry's knack of doing things faster and cheaper, will result in a greatly improved breed of machine tools," was the way one panel member expressed it.

Many European parts plants, it was brought out, cover a million to a million and a half sq ft of manufacturing area. Particularly in Germany, European manufacturers should be considered as "new industries" from the standpoint of machinery, equipment, and tools.

In addition to extensive visits to this country, European companies spend a great amount of time in development and research. In several European plants, college graduates spend as long as two years in manufacturing before they are permitted to function as engineers.

Apprentice programs include physics, mathematics, world history, and general world economics —in addition to subjects necessary to become a toolmaker.

European manufacturers are using more testing and inspection operations than we do. Equipment is usually automatic with lights, dials, or sound to indicate acceptable or unacceptable parts.

Many European plants are building their own specialized machine tool equipment.

Materials handling techniques are showing excellent progress. In some plants in-process floats are held to a minimum and stock is kept moving. Storage of raw materials and parts "is going up in the air," it was suggested. To conserve floor space, some manufacturers' storage facilities extend 25 to 30 ft high. A special cab-and-fork combination which utilizes an overhead crane is used to move stock vertically and horizontally. The stacker-crane used dead ceiling space; also, it makes it possible to use 5 ft passageways.

Panel members agreed that it would be well worthwhile for Americans to visit European plants. Items well worth seeing include transfer presses, die cast equipment, plastic molding, grinding, and forging equipment.

Questions from the floor brought out the fact that, at present, European labor rates are about half of U. S. rates.

Materials costs are much higher in Europe but low labor costs make it possible for them to sell machine tools competitively in America.

Economic pressure to use cast iron and kirksite dies is less than it is here because labor costs are lower. However, efforts are being made to gain acceptance of low cost tooling because labor costs will undoubtedly not always remain as they are today.

Communism is active in labor unions in Europe but this influence is often offset by bonus systems and other types of incentives. There is very little Communist influence in free Germany; in France the influence of the Communists is "quite easily noted."

Improving the Six

Based on paper by

F. R. Kishline

American Motors Corp.

AMERICAN Motors has been developing its L-head and valve-in-head 6-cyl engines to take full advantage of recent improvements in the quality of regular-grade fuel. As a result, the compression ratio has been raised from 7.5/1 to 8.7/1 with consequent increase in efficiency and nominal gain in power.

The 196 cu in. 6-cyl, valve-in-head engine introduced in 1956 was the end result of a series of experimental programs launched in 1945 to evaluate major design factors. The final production design was essentially a combination of two well-proved designs. It comprised the stiff yet light-weight crankshaft and cylinder block of the Rambler L-head engine, and a scaled-down version of the cylinder head, valve gear, and combustion chamber of the larger Ambassador six.

This engine had a wedge-type combustion chamber and gave acceptable performance on regular-grade fuel with a compression ratio of 7.5/1. However, increasing the compression ratio to take advantage of higher fuel octane quality produced an objectionable amount of combustion roughness. It was evident that this excessive roughness was a characteristic of the combustion-chamber shape, because satisfactory results had been obtained with experimental chambers based on other valve arrangements, using the same block and crankshaft.

Cylinder pressure versus time measurements were made, using a strain-gage pickup with an integral spark plug, because space limitations prevented installation of a separate pressure pickup. Graphical analysis of oscilloscope photographs revealed values of peak pressure and rate of pressure rise in this 1956

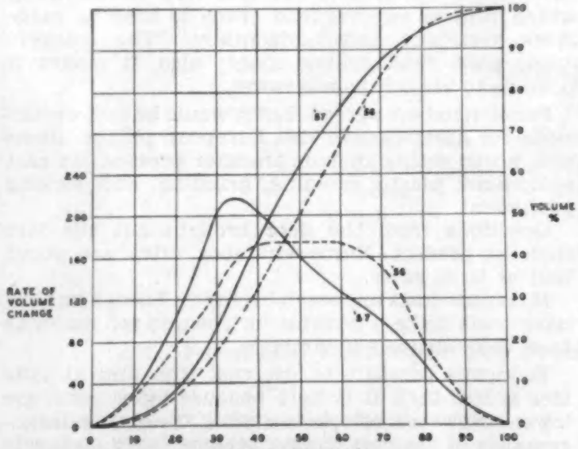
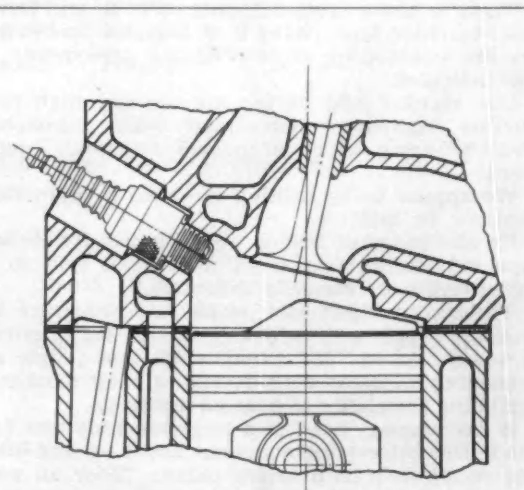


Fig. 1—Curve of chamber volume and rate of volume change versus flame travel distance. Rate of volume change is also proportional to flame front area at any distance from the spark plug. This provides a handy and accurate guide for predicting and measuring changes in volume distribution.



1957 COMBUSTION CHAMBER
8.25:1 COMPRESSION RATIO

Fig. 2—When rate of volume change curve (Fig. 1) was found to deviate from composite curve of smooth engines, piston head shape in 1957 Rambler six engine was altered to approximate volume distribution of a smooth engine.

to Match V-8 Advances

engine to be substantially higher than those found acceptable in other engines of the same compression ratio.

Changing Shape of Piston Top

Obviously, a change in combustion-chamber shape was needed, but the shape within the head was fixed by design requirements for valve and port locations, spark-plug location, and by expensive machine tool and pattern equipment. Therefore, the only practical way to alter chamber shape was to change the shape of the piston top. This was done by using a modification of the plaster cast volume analysis technique employed by Alex Taub over 22 years ago. Instead of plaster casts, lead castings were used. These were cut spherically around the spark-plug center in 20 increments of radius.

The curve of chamber volume versus flame travel distance is differentiated to show the rate of volume change, which is also proportional to flame front area at any distance from the spark plug (Fig. 1). This curve is admittedly a very rough approximation of the actual combustion characteristics in the chamber, but it has been found a convenient and accurate guide for predicting and measuring changes in volume distribution. Without such a tool it is very difficult to visualize the effects of design changes.

The rate of volume change, as shown in Fig. 1, was found to deviate considerably from a composite curve of several smooth engines, so a piston head shape was developed to approximate closely the volume distribution of a smooth engine. Dynamometer and road tests substantiated the prediction of combustion roughness reduction and showed a decrease in octane requirement permitting a further compression ratio increase. The 1957 chamber, using this piston design is shown sectionally in Fig. 2.

Analysis of Combustion Roughness

Experience shows the degree of combustion roughness to be closely related to the rate of pressure rise. It is related in some degree to the value of peak pressure. However, severe roughness can occur at part throttle with reduced peak pressure, so this probably is not a major influencing factor. Since combustion roughness, power, and octane requirement are functions of spark advance, combustion chambers are

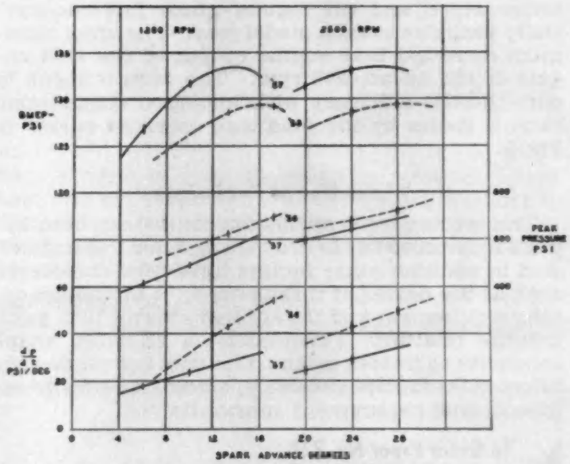


Fig. 3—Comparison of combustion chambers by plot of bmep, peak pressure, and rate of pressure rise versus spark advance permits ready selection of best compromise of spark advance to achieve maximum power and minimum harshness.

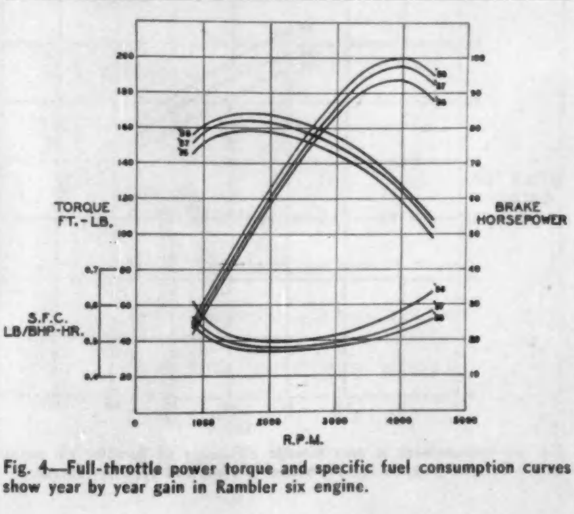


Fig. 4—Full-throttle power torque and specific fuel consumption curves show year by year gain in Rambler six engine.

compared by plotting bmep, peak pressure, and rate of pressure rise versus spark advance in Fig. 3. The best compromise of spark advance for maximum power and minimum harshness can be selected easily. In Fig. 3 the 1956 engine at 7.5/1 compression ratio is compared with the 1957 engine at 8.25/1, at two representative engine speeds.

A further gain in regular-grade fuel octane quality allowed the compression ratio to be increased to 8.7/1 in the 1958 engine, without appreciably increasing combustion roughness and with consequent improvement in efficiency. The primary aim in raising compression ratios has been to get more mpg on regular fuel, although nominal increases in power have been produced, as shown in Fig. 4. This curve compares full-throttle power torque and specific fuel consumption of the 1956, 1957, and 1958 engines. It represents actual net output at the flywheel when installed in the car with air cleaner, fan, exhaust system, automatic spark advance, under-hood air temperature, and the regular-grade fuel commercially available in each model year. The gross maximum corrected bare engine output of the 1958 engine is 127 hp at 4200 rpm. The improvement in part-throttle efficiency with increased compression ratio is shown by the road load economy curves in Fig. 5.

Wider Use of Techniques

This technique of combustion control has been applied to improve the L-head six and our V-8 engines. And in addition other factors have been considered such as the degree of turbulence as it influences octane requirement and the ability to burn a lean part-throttle mixture. Fortunately, a chamber shape conducive to smooth combustion does not necessarily affect these factors adversely, indeed, it seems to reduce octane requirement substantially.

To Order Paper No. 32A . . .
. . . on which this article is based, turn to page 5.

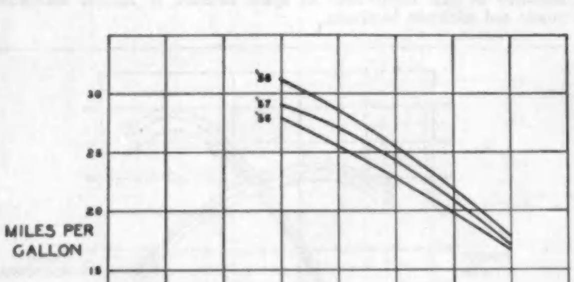


Fig. 5—Improvement in part-throttle efficiency of Rambler six engine with increased pressure ratio is shown by road load economy curves.

Six areas for saving $

Based on secretary's report by

A. F. Eskelin
Northrop Aircraft, Inc.

AREAS of potential economic gain which will be enhanced by the development and introduction of numerically controlled machine tools include:

1. Product design
2. Tooling
3. Production
4. Inspection
5. Weight and interchangeability
6. Engineering changes

Product design and engineering will be given much greater freedom in product concept because of the expanded operational character and versatility of numerically controlled machine tools. Designers will be able to create parts previously considered uneconomical in production. Therefore, it is of the greatest importance that the design engineer in any company become thoroughly familiar with these tools and their potential.

Tooling

Tooling can be reduced because numerically controlled machine tools lend themselves readily to more simplified tooling concepts. Numerical control virtually eliminates the necessity for hand-making operating templates and tooling tools, the latter of which are normally a hidden cost factor in the regularly accepted tooling project. These advantages, in turn, are conducive in lowering the time span required for a production cycle, from the engineering drawing to the finished part. The reduction of the number of tools, in a family of tools, will also result in a reduced tooling maintenance cost. In addition, numerical control makes possible the minimum of

through Numerical Control

tool storage area requirements, thereby freeing more of the factory areas for actual parts production.

Production

Numerical control makes possible maximum product realization. This is true because the human factor is reduced as a directing force and, therefore, the operating cycle can be established as an accurately calculated time span. This enables industrial engineers to determine the character and size requirement of production flow through the machine shop, and to establish the required tool and machine tool count by actual calculation, rather than by educated guess.

Inspection

Normal fabrication requires accurate and intelligent inspection of parts, at great expense, to maintain good production flow. Numerical control will enable the manufacturer to produce consistently parts of the highest quality, with only a minimum of inspection required per part. Since numerically controlled machines are operated from prepared programs, dimensional control is established, and as a result, will reduce the manufacturer of scrap, by operator error, to a minimum.

Weight and Interchangeability

Numerical control is able to operate a machine tool to the highest limits of its tolerances, thereby effecting a very close tolerance in the part, which, in turn, means reduced weight and excellent interchangeability.

Engineering Changes

Numerical control lends itself readily to the introduction of engineering changes. This results in reduced production cycle elapsed time and tooling coordination.

All of the aforementioned factors are essential since all of their benefits result in the serious reduction of what is often classified as fatal lead time. Last but not least, however, we should consider in these economic advantages the natural versatility which is lent to any of these tools merely by adopting numerical control.

To Order Paper SP-321 . . .
. . . on which this article is based, turn to page 5.

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panel secretary:
A. F. Eskelin, Northrop Aircraft, Inc.

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W. P. Robertson, Northrop Aircraft, Inc.

W. J. Kinney, Douglas Aircraft Co., Inc.

O. A. Foss, North American Aviation, Inc.

L. H. Ferrish, Lockheed Aircraft Corp.

M. C. Copold, General Dynamics Corp.

William R. Strickland

1875 – 1958

William R. Strickland

WILLIAM R. STRICKLAND, 1929 SAE President and pioneer in the automotive industry, died February 16 in Melbourne, Fla., where he had lived for the past several years.

Strickland retired in 1930 as assistant chief engineer of the Cadillac Division of GMC. Although ill health forced his retirement, he later recovered to enjoy 28 years of active and useful living, pursuing his numerous, varied interests and hobbies. During the last several years in Florida, he devoted much of his time to golf and residential architecture. He also spent many hours in helping plan trust funds for the Washington Cathedral and Massachusetts Institute of Technology.

He was born on March 19, 1875 in Cincinnati, Ohio. While still a child, Strickland's family moved to Aspen, Colo., where he spent most of his boyhood. As early as age 16, he was a camp cook in a silver mine. . . . One day, while burying refuse at the back of the camp, he uncovered one of the richest silver veins in the district. Overnight, he became a local hero and celebrity. He lived in the West during some of its now-famous rough and tumble days. . . . On one occasion, although he himself was too young to join, he donated his horse to an organized party which went off to quell an Indian uprising in a nearby territory.

Strickland went to Massachusetts Institute of Technology after completing his preliminary education at Chicago Manual Training School. In 1898, when the time came for him to receive the Bachelor of Science Degree he had earned, he had joined the Navy to fight the Spaniards. He was aboard the gunboat "Bennington" ploughing through the Pacific to Hawaii, when his M.I.T. graduation exercises took place . . . and he couldn't hear the cheers that accompanied the standing ovation which greeted the reading of his name *in absentia*.

Soon after his discharge as an Ensign, he went to work building railroads and constructing power dams . . . a natural result of the Civil Engineering courses which had dominated his curriculum at M.I.T. These early engineering tasks took him to Puerto Rico and other areas at that time considered remote.

In 1908 Strickland moved to Detroit and the American Radiator Co., where he became assistant manager of the company. From there he went to Peerless Motor Car Co., where he developed that company's first V-8 engine. He served Peerless as assistant chief engineer, and later as chief engineer and vice-president.

He joined GMC in 1922 by way of General Motors Research, when that group was still in Dayton, Ohio. There his first assignment was to work on the counterweighting and balancing of the Cadillac 90 deg two-throw crankshaft. Shortly, however, he went to Detroit as assistant chief engineer of the Cadillac Motor Car Co. Among the accomplishments in which he played a major role at Cadillac were creation of the LaSalle—a companion-car to the Cadillac—and the once famous Cadillac V-16.

While at Cadillac, Strickland and his son, Randolph L. Strickland, took a test trip in August of 1927 in one of the first two 1928 Cadillac models to come off the assembly line. Their trip included driving through Independence Pass in the Rocky Mountains . . . where 41 years previously (March, 1886) W. R. Strickland and his father had crossed on a sledge, which had tipped over near the top of the Pass. (The December 1954 SAE Journal carries a photograph of the 1927 father-and-son trip.)

Elected to SAE membership in 1912, Strickland was chairman of both the Cleveland and Detroit Sections before becoming SAE President in 1929. He was chairman of the Cleveland Section in 1917–18 and of the Detroit Section 1925–26. He also served SAE as second vice-president representing Motor Car Engineering in 1924 and first vice-president in 1928.

THIS MAKE-BELIEVE MISSILE COMPANY'S STAFF included (starting with the man in center foreground and going to his left around table) R. E. Day, Tracy Brooks, D. C. McLees, R. F. Smith, (standing) A. T. Letsinger, (at far end of table) C. L. Bates, F. H. Sharp, P. M. Klauber, W. T. Immenschuh, W. W. Vyvyan, (standing) Paul Brady, and (seated at the right end) R. G. Sharp, chairman of the session.

INFORMATION in the accompanying article was developed in conferences of the mythical Hit Missile Co. staged at a session of the SAE National Aeronautic Meeting in Los Angeles. The dramatization began with a gathering of the engineering management team called to discuss need for additional supervisors created by a new contract. It continued through an audience-participation "buzz" session and several more scenes, as described on page 90 of the November issue of SAE Journal. It ended, after an audience-participation period and several more scenes, on a realistic note: the announcement that the contract had been cancelled.

That was just a few hours before the announcement of the first Russian earth satellite. Because the contract may have been reinstated since — and the suggestions can be applied in any engineering business — SAE Journal presents on these pages the ideas brought out in the theater-in-the round production staged by SAE San Diego Section, reported by R. E. Day of Solar Aircraft Co., and titled

The Sliderule Route to

From the Engineer's

- First requisite for an engineering supervisor's job is technical ability. A man must have absorbed his engineering fundamentals and gained a reputation for successful accomplishment of technical work.
- Then he must develop the ability to deal with people as well as things and ideas — especially nontechnical people in other departments. That means he must learn to evaluate people as to their ability to get a job done and get it done on time. He must acquire the knack of making a firm decision and rendering it to his subordinates in an understandable and palatable manner. For occasions when the decision isn't his to make, he must become adept at persuasion, to sell ideas both up and down the chain of command. The earlier in a man's career these skills are developed, the better. But if a man hasn't given much thought to them before deciding he wants to prepare himself for a supervisor's spot, he'd better start then.
- His appearance and manner should be the kind that get him listened to by his coworkers, he ought to remember.
- He should develop cost-consciousness — that is, an appreciation of the cost of an engineering-hour and the business judgment to get the most value out of it.

From the Company's Direction

- A company should create an atmosphere that encourages men to learn how to be good supervisors. But the company should leave the responsibility for development with the man himself.

- "Encouragement" may take such forms as tuition-reimbursement plans, recognition in personnel records of courses completed, and notification to the man's supervisor. It helps to counsel prospective supervisors individually on what their lacks are and where they can take courses. This counseling is done with men previously judged to have supervisory potential.

- The company should see that the potential supervisor gets an overall understanding of company operations and policies, as well as training in supervisory techniques.

- Solving problems is the "core task" of the supervisor, psychologists now feel.

- The supervisor must learn to be "available" and to listen. If he is too quick to defend what he's said or how he's acted, people will tell him only what he wants to hear.

- Lectures on how to supervise aren't so effective as sessions where the student participates actively. The more participation, the better the results.

- People learn faster and more if there's an element of reward involved. Don't overlook either intangible rewards or tangible rewards.

- To build up the information, skills, and attitudes men need to become supervisors, a company can take advantage of college programs in management, conferences run by professional societies, psychological consultants to work with individual supervisors to help them understand themselves and other people, and testing services.

- This holds in the planning of the man's development program too. It's wiser to lead a man to figure out his own goals and the steps he needs to take to attain them than to tell him what to do.

- Another way to encourage men to learn to supervise is to create an Educational Steering Committee or an Engineering Management Development Committee made up of the most respected people in engineering management. Let it be known that the company attaches much importance to helping people grow into supervisory spots.

- See that an individual's efforts at self-improvement get him a pat on the back from his immediate supervisor.

- Back up the supervisors the company already has. Don't make men feel the supervisor's position is an undesirable one.

- If, after you've done your best in selecting and developing a supervisor, he turns out to be unsuited to management, remove him. You have a responsibility to his subordinates to give them good supervision. But in removing him, remember to help him save face. Try to make efficient use of his abilities in a nonsupervisory position. Remember, he may have been unhappy as a supervisor and may be glad of the change. But you can lose all of your investment in him and ruin his career if you make him appear a failure.

- Remember that being the boss isn't the only satisfaction in life. Indeed for many people it's no satisfaction at all. For most of us our greatest contributions and our deepest satisfactions in business come from other forms of participation.

- Before putting a man in a supervisory job, try him out on parts of the supervisor's job. Observe him and coach him. For example, a supervisor may assign a likely looking man to prepare a conference and maybe run it. After it's over the supervisor should compliment what was done well and point out how other parts could have been done better. This kind of assignment reveals whether a man is able to delegate. If he isn't willing to let others play parts that will bring credit to them, he's not going to delegate or give them credit later as a supervisor. He probably is an insecure person.

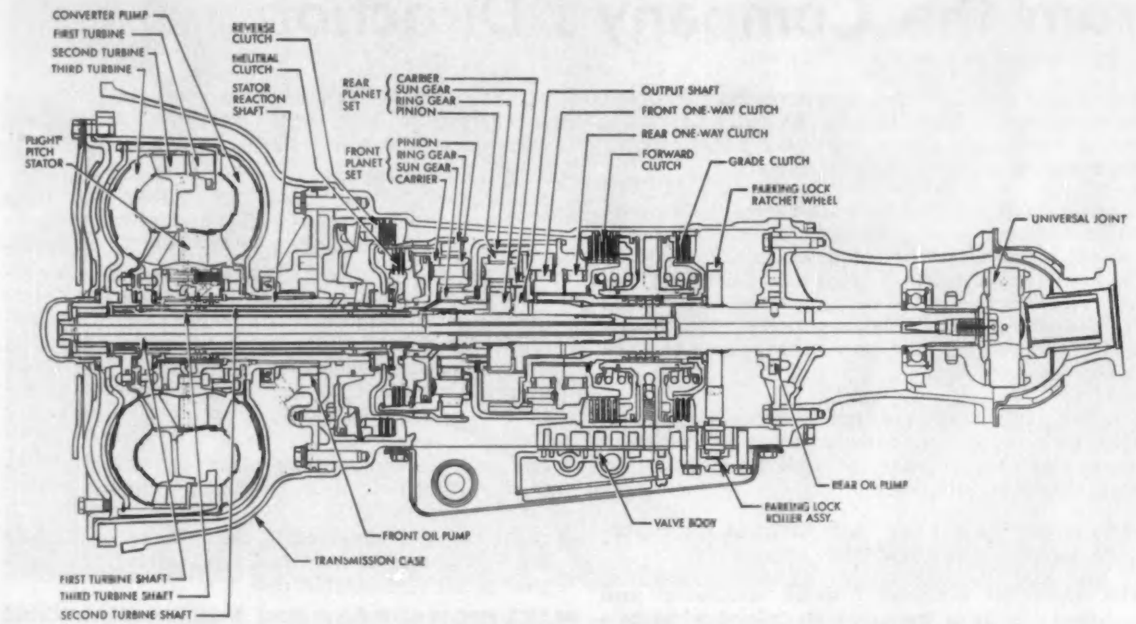
- Get middle management people to gather their first-line supervisors together periodically to discuss what each is doing to develop and train his own people.

- Before you send a man to an outside conference — or an SAE meeting — be sure he knows — and you know — what the objectives for his attendance are. Talk over with him what kinds of information he should be on the look-out for. Encourage him to make the personal contacts that will increase his satisfactions in his being part of the engineering world.

Supervision

Direction

- He should observe the methods used by supervisors to get good results in carrying out such typical functions of the post as running a meeting, maintaining neatness in work areas, and stimulating subordinates.
- Prerequisites to any supervisory job are the personal attributes of integrity, genuineness, tact, physical stamina, initiative, self-confidence, and enthusiasm. Before setting his sights on a supervisory job, an aspirant had better examine his own character to determine whether he qualifies on these counts.
- He'd better see to it that his personal life is well organized, too.



Buick's new Flight-Pitch Dynaflow has three turbines, uses no gear shifts.

New turbine added to Buick's DYNAFLOW

Based on a paper by

Forest McFarland and C. S. Chapman, Buick Motor Division, GMC

THE Buick Flight-Pitch Dynaflow employs three turbines, each geared at its own speed ratio to the driven shafts. Unlike almost all other automatic transmissions, it uses no gear shifts.

It contains a 5-element torque converter — an engine-driven pump member, three turbines, and the stator — combined with two planetary gearsets.

How New Buick Transmission Differs from Earlier Versions

The Buick Flight-Pitch Dynaflow differs from its predecessor in a number of ways:

1. It consists of a torque-converter arrangement carrying three driven turbine members, one geared to the rear axle by a 2.86 ratio planetary gearset, a second geared to the rear axle by a 1.54 planetary gearset, and a third turbine driving directly to the rear axle. This compares with the previous model, which carried the first turbine geared to the axle by a 1.6 planetary gear ratio and the second directly connected.
2. This results in a stall torque ratio of 4.5 in the new transmission compared to 3.5 in the previous unit. This increased torque capacity eliminates the need for a low gear of 1.8 ratio, as carried by the Variable-Pitch Dynaflow.
3. The "switch the pitch" arrangement for turning the reactor blades to increase performance has been made a continuously variable feature on the new unit, whereas it was accomplished on the former by "kicking down" past full throttle.
4. A grade range for hill descent only is similar to the low range in the previous unit.
5. An improved park arrangement is used to lessen the friction in the mechanism. It also greatly reduces shifting effort in getting out of park position.
6. More extensive use of aluminum, which is, in part, responsible for about a 30-lb saving in weight.

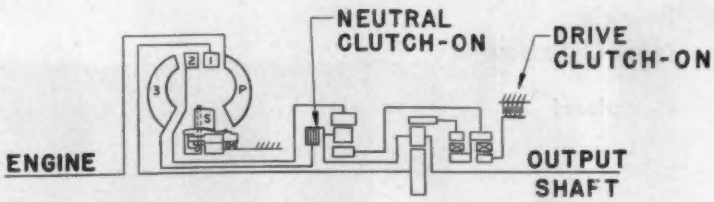
For a description of the first Buick automatic transmission and the changes that have been made through the years, see the following articles in SAE Journal:

1. For the first unit, which introduced the torque-converter design: SAE Journal, April, 1948, pp. 23–29: "Buick's Dynaflow Drive," by C. A. Chayne.
2. For introduction of geared first turbine: SAE Journal, June, 1954, p. 98: "Twin Turbine Raises Dynaflow's Efficiency," by R. J. Gorsky.
3. For introduction of variable-angle reactor blades: SAE Journal, October, 1955, pp. 28–29: "Buick Switches the Pitch," by R. J. Gorsky.
4. For introduction of second reactor between first and second turbine: SAE Journal, February, 1956, pp. 50–56: "What's New about 1956 Dynaflow," by R. J. Gorsky.

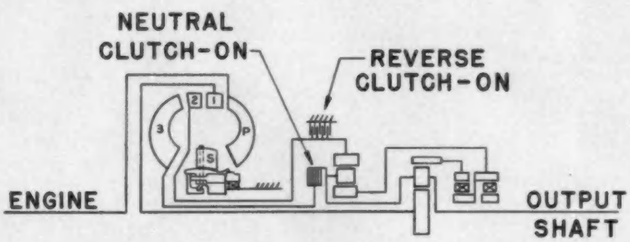
To Order Paper No. 29A . . .
. . . on which this article is based, turn to page 5.

How it operates

Drive range



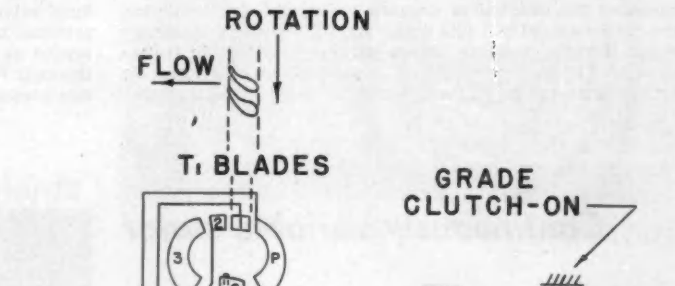
In drive range, the drive and neutral clutches are engaged as shown above. The first turbine is connected to the sun gear of the rear planetary gearset, which multiplies the turbine torque by 2.86/1. The ring gear is the reaction member being grounded through both one-way clutches and the drive friction clutch. The planet carrier, which is the output member, is connected to the transmission output shaft. The second turbine is connected to the ring gear of the front planetary gearset, which multiplies the turbine torque by 1.54/1. The sun gear is the reaction member and is grounded through the rear one-way clutch and the drive friction clutch. The carrier of the front gearset is again the output member and is connected to the output shaft through the rear carrier. The third turbine is connected directly to the output shaft through the neutral friction clutch. The stator is grounded to a reaction shaft through a one-way clutch. The stall torque ratio in drive range is 4.75/1.



Reverse range

In reverse, the reverse and neutral clutches are engaged as shown here. The first turbine and rear sun gear drive the rear ring gear rearward, since the carrier is connected to the output shaft. This results in a forward torque on the carrier. The rear ring gear drives the front sun gear rearward through the front one-way clutch. This sun gear drives the front carrier rearward since the outer ring gear is grounded through the reverse friction clutch. The reverse torque on the front carrier is considerably higher than the forward torque on the rear carrier. Since they are connected, this results in a net reverse torque to the output shaft. The reverse torque ratio at stall is 4.50/1.

Grade range



In grade range, the grade clutch (which is a hill-retarding mechanism) is engaged and the other friction elements are released. The grade clutch is necessary to hold the rear ring gear from rotation, since the one-way clutches allow it to turn forward in drive range. The gearset turns the first turbine at 2.86 times output speed. The first turbine acts as an axial-flow pump driving the fluid in the same direction as the pump of the converter in drive. The flow established by the first turbine drives the torque-converter pump, which drives the engine, effecting engine braking. Varying the throttle opening will change the amount of braking, although the car cannot be driven in grade range since the first turbine freewheels at low vehicle speeds in normal driving operation. In the neutral and park ranges, all of the friction elements are disengaged.

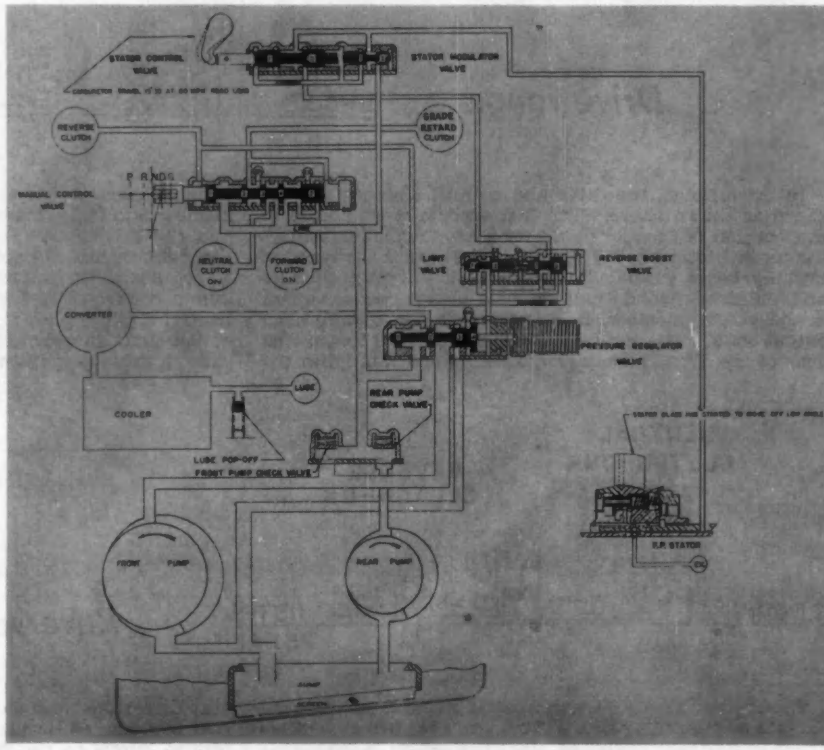
continued

Buick's New Dynaflow

— continued

Some components

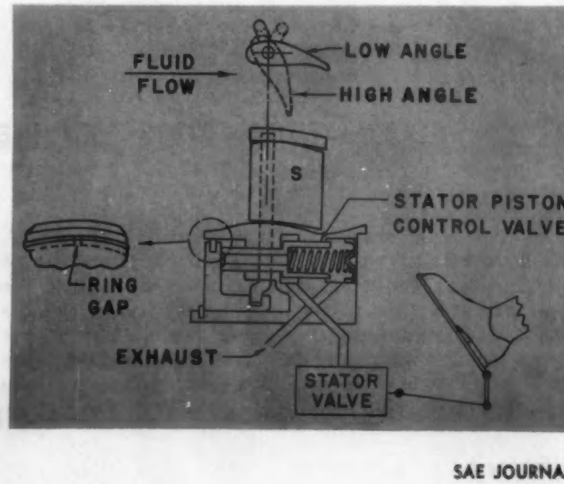
Hydraulic control diagram



The hydraulic control diagram in drive range at 60-mph, road load is given here. Note that the transmission controls are relatively simple by industry standards. There are two valves that are common to all automatic transmissions: the manual or selector valve and the line pressure regulator valve. The stator modulator valve is similar to the throttle pressure valves in many automatic transmissions in that it produces a pressure proportional to throttle movement. This pressure is directed to the continuously variable stator, where it controls the movement of the stator. The stator pressure is also used to increase the line pressure to provide sufficient torque capacity for the friction clutches as engine torque increases. The limit valve provides a means of limiting the maximum line pressure to that value required to hold wide-open throttle torque at stall. The stator modulator pressure is routed through the stator valve in such a manner that minimum line pressure is carried at road load at normal road speeds.

Continuously variable stator

The continuously variable stator blade and control mechanism are shown at right. The stator blades have steel cranks with crank throws inserted in a groove of the stator piston similar to the arrangement of the Variable-Pitch Dynaflow. The axial movement of the stator piston rotates the stator blades about the center of the crank. The position of the piston is determined by the stator piston control valve. In the low angle or normal driving position, the end of the hollow valve is touching the stator piston, sealing the chamber behind the stator piston. The torque-converter charging pressure is equalized on both sides of the piston, and the fluid flow forces on the stator blades tend to turn the cranks in a direction to force the

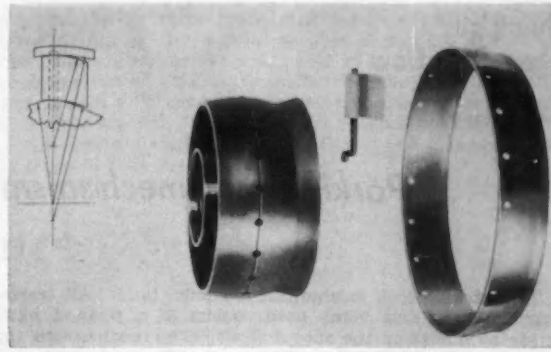


described

piston to the left against the snap ring. There is a gap in the sealing ring at the outer diameter of the piston, which permits the torque-converter charging pressure to fill the piston cavity and balance the pressure on the two sides of the piston. As the stator modulator valve increases the stator pressure, the pressure acts on the valve area, moving the stator piston control valve to the right against the valve spring. When the stator piston control valve leaves the piston, it opens the exhaust hole in the center of the valve. This allows the oil pressure in the piston cavity to be vented, which unbalances the pressure forces of the piston. The pressure unbalance is maintained by the orifice effect of the gap in the piston sealing ring, which prevents the converter oil from escaping in excessive quantities. The piston moves to the right until it nearly touches the valve, forming a partial seal of the piston cavity. The oil flowing through the gap in the piston sealing ring produces a pressure in the cavity of the piston such that the differential force on the piston balances the flow forces of the stator blades acting through the cranks on the stator piston. Therefore, the piston moves toward the valve in such a manner as to regulate a pressure in the cavity until this force balance is reached. The area of the piston is such that the forces involved are large enough to minimize friction effects.

When the stator pressure drops as the driver lifts his foot from the accelerator, the stator piston control valve spring forces the valve to the left against the piston. This seals the exhaust opening in the valve. The torque-converter charging pressure, acting through the gap in the piston sealing ring, balances the pressure on the piston and the stator blade forces, acting through the cranks, force the piston to the left toward the snap ring.

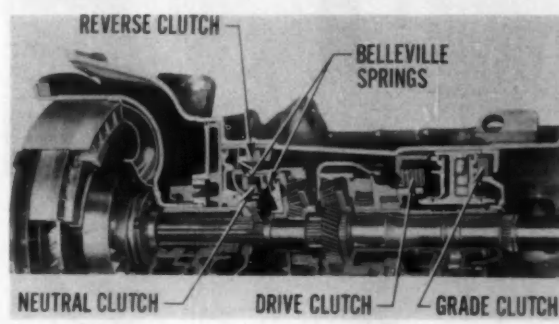
The valve areas and spring force are set up to allow the



stator blades to leave the low angle position at half throttle and complete the change to high angle just before the throttle is wide open. The total travel of the piston is ¼ in. and the stator blade angle change is 55 deg.

The outer diameter of the stator assembly is machined spherically, with its radius at the intersection of the centerline of the stator blade crank and the axis of rotation, as shown above. The bottom of the stator blade is cut off to form an arc slightly larger than the sphere on the stator hub and tangent to it at the crank. This keeps the clearance between the hub and the pivoting stator blade to a minimum as the blade turns to the various positions. The outer core ring is also formed as a sphere about the same center as the stator hub. The outer end of the stator blade is cut off at a slightly smaller radius so that the stator blade touches the ring only at the crank and not at the tip of the blade. This prevents any slight out-of-round condition in the outer core ring from causing a sticking condition as the stator blades turn.

Friction elements



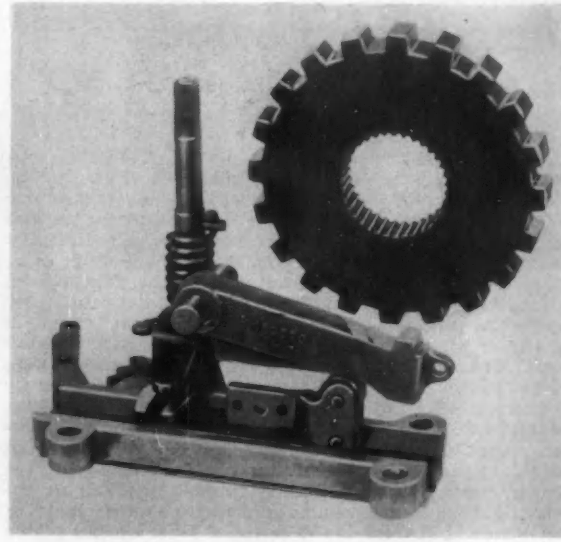
The friction elements are the multiple disc clutches shown here. Since the reverse and grade clutches are disengaged and spinning freely in drive range, the clutch drag losses had to be kept to a minimum. The most critical factor influencing these losses is the amount of oil used to cool the clutch plates. The outer chambers in which the clutch plates turn were vented to prevent the oil from accumulating between the plates. The chamber of the grade clutch was effectively dammed by the clutch backing plate, since the lower portions of the clutch plates are below the normal oil level. The oil vents are at the sides and top of the clutch backing plate for this reason. The reverse clutch backing plate has oil vents around its periphery, since it is above the oil level.

The neutral and reverse friction clutches have three friction plates as well as belleville springs, which serve as piston return springs and also as levers to multiply the piston force. The belleville springs have a "flat" characteristic after reaching the peak in the initial part of the curve. This flat portion of the curve allows a constant spring force with the normal variation in clutch pack tolerances. Both belleville springs were designated without any fingers or slots, from which it is difficult to remove sharp edges and burrs.

The grade clutch has three friction plates with a direct-acting piston. The forward clutch has five friction plates also with a direct-acting piston.

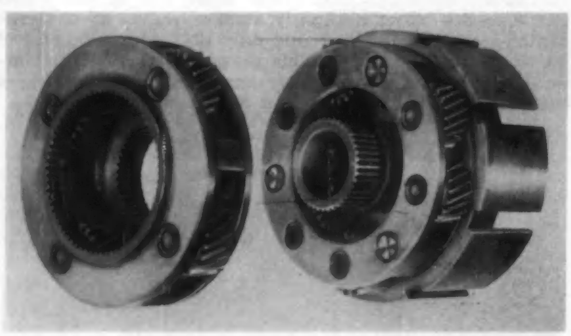
continued

Parking lock mechanism



The parking lock mechanism is shown here. All transmission locks now being used consist of a pivoted pawl engaging a gear on the output shaft. The mechanisms for actuating the pawl differ. The most difficult problem involved in the design of a parking pawl actuating mechanism is the reduction of release effort when the pawl tooth is heavily loaded, which occurs when the car is parked on a grade.

A roller mechanism was developed to minimize this effort. The shift lever on the wheel is connected to the roller slide through the transmission linkage. When the rollers move the pawl into engagement, the rollers are wedged between the flat on the pawl and the flat surface of the bracket, retaining the roller assembly by the separating forces between the gear tooth and the pawl tooth. The two surfaces bearing on the roller are parallel so that the main forces to overcome in releasing the pawl are the friction forces of the roller contact points. The pins in the rollers are pressed into the rollers and are a loose fit in the slide assembly. Since they are of relatively small diameter, their friction forces are negligible.



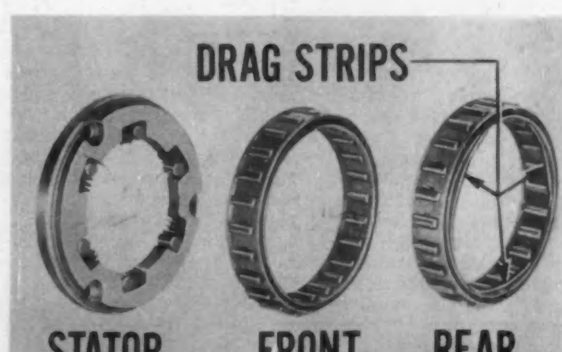
Planet carrier assemblies

The planet carrier assemblies are shown here. The four planet pinions in the rear gearset take just under five times engine torque at stall in drive range. The six pinions in the front gearset take nine times engine torque in reverse and stall. The number of teeth and helix angle in the front and rear ring gears are the same. This is also true of the sun gears. The planet pinions in the two gearsets are identical.

Three one-way clutches

The three one-way clutches are shown at right. The stator one-way clutch located in the torque converter is an internal cam and roller clutch with waved individual energizing springs. This one-way clutch does not carry much torque (about 170 lb-ft) and is of conventional design.

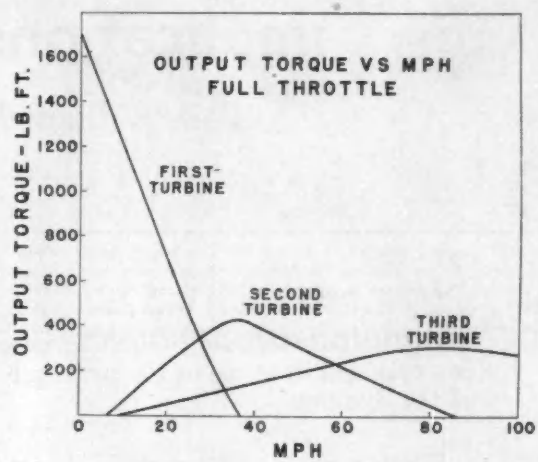
The two one-way clutches located inside the transmission consist of sprag assemblies and circular races. The sprag clutches were used because the sprag contours can be made in such a manner that the sprags tend to "tuck in" or engage as the sprag assembly is rotated. They also have good capacity for a given space. The rear or "T-2 sprag assembly" has three bronze drag strips on the inner cage, which tend to make the assembly rotate with the inner race. Since the inner race is stationary in drive



range, these drag strips hold the sprag assembly stationary and cause the rubbing velocity between the sprags and race to take place at the outer race, where centrifugal force tends to throw the lubricating oil. The front or "T-1 sprag assembly" has centrifugally engaging sprags with no drag strips. The drag strips were not used because the outer race is stationary in grade range with the inner race rotating at high speed. Anchoring the sprag assemblies to the rotating inner race would allow centrifugal force to throw the individual sprags against the outer race, causing excessive sprag wear in grade range. Since both the inner and outer races freewheel in the same direction in drive range, the rubbing speeds between sprags and races are not so high that drag strips are needed.

The required static torque capacity of the sprag one-way clutches is 1080 lb-ft.

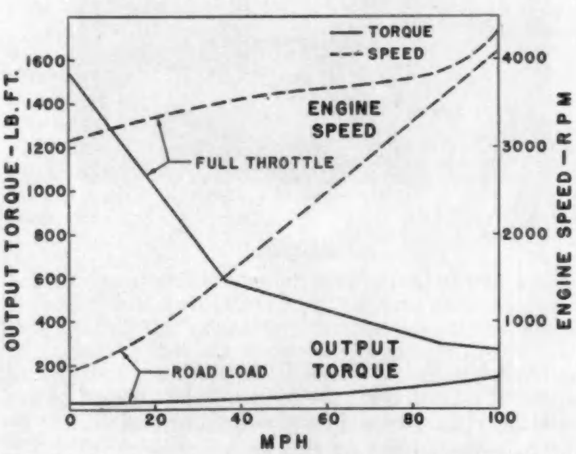
New Dynaflow's performance



Total output torque

Total output torque at wide-open throttle in drive range for the three turbines and their gearing is shown at right. Note that, at stall, first turbine is contributing all of the torque, with the second and third turbines having slight negative torques. As the vehicle accelerates, the second turbine torque increases until it reaches a maximum at 1390 output rpm or 35 mph. The third turbine torque also increases with increasing output speed and reaches a maximum at 3400 rpm or 88 mph.

The total output torque curve is the summation of the three turbine torque curves.

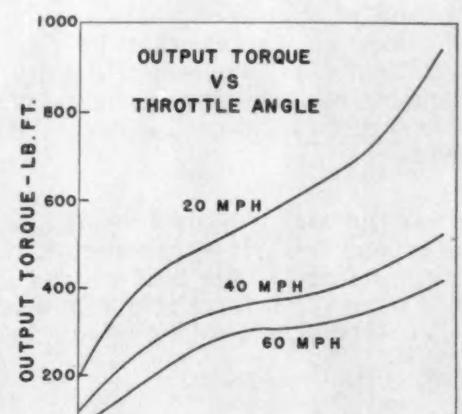


Output torque and input speed

Output torque and input speed are compared at left for wide-open throttle (high stator angle) and road load. Difference between the two torque curves indicates the torque available for acceleration. The continuously variable stator blade pitch enables the driver to select any value of torque between the curves he desires at any given speed.

Output torque vs. carburetor opening

Output torque versus carburetor opening at various road speeds is shown at right. Note that the output torque is nearly linear with the carburetor opening over the speed range. This means that the movement of the accelerator pedal can be controlled easily to select the exact level of performance the driver desires.



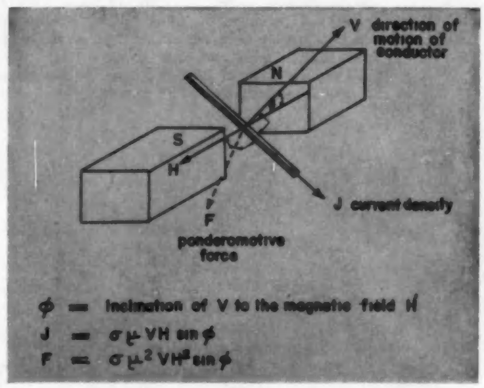
Magnetohydrodynamics

is an old field with new implications for engineers

Excerpts from paper by **William McIlroy** Member of Scientific Research Staff, Republic Aviation Corp.

Magnetohydrodynamics can be explained in terms of the principle of the dynamo:

When a conducting wire is thrust through a magnetic field of strength H, with a velocity V whose direction is perpendicular to the wire and is inclined to the direction of the H field at an angle ϕ, an electric field (E_{ind}) is induced in the wire.



The value of the induced E field is equal to the product of the permeability of the medium μ, the strength of the magnetic field H, and the component of the velocity normal to the H lines (V sin ϕ), that is, $E_{ind} = \mu HV(\sin \phi)$. A current of density J equal to σE_{ind} will flow in the conductor, where σ is the conductivity of the wire.

As the wire is pushed through the magnetic field, it experiences a resisting force F per unit volume of the wire. This force acts in a direction perpendicular to both the H field and the E field, and equals μJH or $\sigma\mu^2 H^2 V(\sin \phi)$. It should be noted that this force is only influenced by the component of the velocity normal to the magnetic lines of force. There is no interaction between H and the velocity component $V(\cos \phi)$ since they both lie in the same direction. This resisting force per unit volume is termed the "ponderomotive force."

MAGNETOHYDRODYNAMICS is concerned with the flow of a conducting fluid in the presence of magnetic and electrical fields. The fluid may be a liquid metal such as mercury or sodium or potassium or a gas at elevated temperatures such as occur behind the bow shock of a high hypersonic missile.

The field of magnetohydrodynamics opens up a seemingly endless stream of bright possibilities, among them:

—the "pinch effect" which keeps ultra hot gases away from the walls of their container, making possible the fusion reactor.
—reduction of aerodynamic heating at the nose of a re-entry missile.
—a plasma engine for flight into outer space.

Although the name magnetohydrodynamics (or hydromagnetics, as it is sometimes called) is a formidable one, the basic principle is relatively simple. It is none other than the familiar dynamo theory, except that we are considering a gas with a comparatively low value of electrical conductivity rather than a solid conductor of high conductivity. There is a coupling between the electrical properties of the fluid and its mechanics, and the motion can no longer be described by the familiar equations of hydrodynamics alone, but only in conjunction with the equations of electromagnetic theory as formulated by Maxwell. The resulting set of differential equations for the magnetic, electric, and velocity fields, and their boundary conditions, becomes quite involved. Few solutions exist at the present time, and only some of the simpler one-and two-dimensional problems have lent themselves to analytic solutions.

Prior to a few years ago, magnetohydrodynamics was principally the concern of the astro- and the geo-physicist. With it the geophysicist was able to advance a theory for the earth's magnetism, and the astrophysicist theories to explain such cosmic phenomena as sunspots, magnetic stars, solar corona, magnetic storms, and the auroras. Today, magnetohydrodynamics is becoming the tool of the engineer.

Ionization

The "plasma" with which magnetohydrodynamics is concerned is an electrically neutral gaseous mixture containing negatively charged particles, electrons, and positively charged particles, ions. Ionization in a gas takes place when the energy level is raised to a point where, due to the violent collisions of the atoms and molecules, the orbital electrons around the atom nuclei are so agitated that they can jump from their ground states to higher levels, and finally are shed, one by one, from the outer orbits to leave positively charged ions. By virtue of this the gas now has free electrons and ions and is capable of being influenced by external magnetic and electric fields. The electrical conductivity is a measure of the degree to which the gas has been ionized.

There are a number of methods for obtaining ionization in a gas:

1. On application of sufficiently high voltage between two electrodes, an electrical discharge is produced which excites and ionizes the gas. When a high radio frequency is used the ionization can

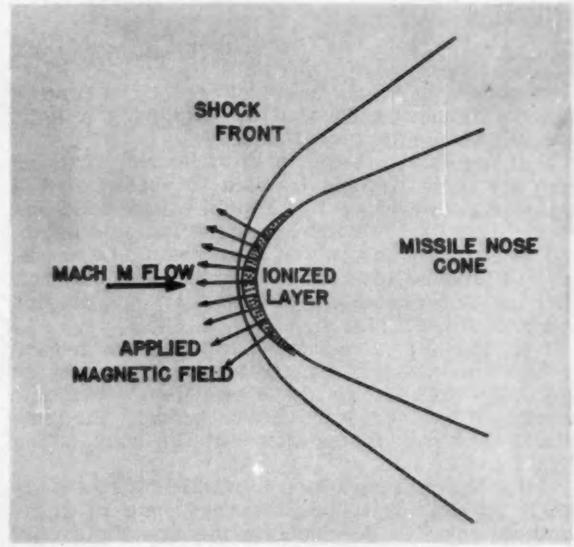


Fig. 1—Ionization occurs in a gas heated to extremely high temperatures as happens when the air ahead of a hypersonic missile is rapidly decelerated through the bow shock wave that forms ahead of the body. At a Mach number around 18, the air is reasonably ionized. In fact, high radio frequency transmission through the blanket of ionized gas formed around the nose of the missile becomes extremely difficult.

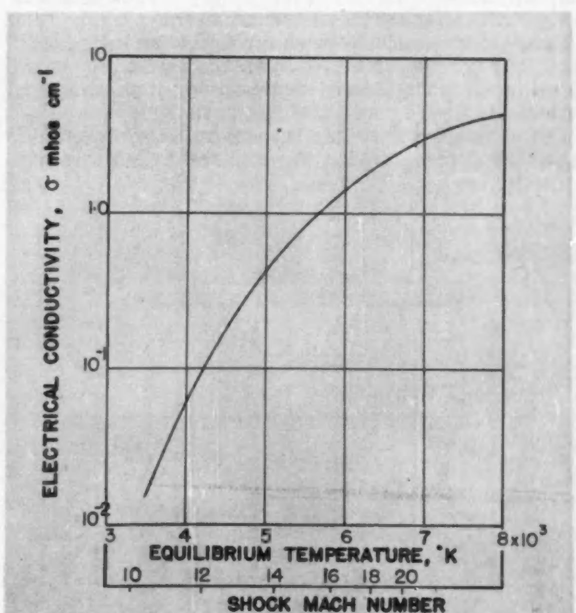


Fig. 2—Electrical conductivity increases with temperature behind the bow shock and the Mach number of the flow ahead of the shock. Value of 2.5 mho/cm, which occurs around Mach 18, is simply the conductivity of a concentrated solution of salt in water.

be produced at much lower voltages. The process can be further accelerated by employing a light source directed at the cathode.

2. If the gas is on the verge of ionizing, particle emitters could possibly be used to accelerate the process. However, a few rough calculations indicate that a prohibitive amount of plutonium, radium, or other radioactive source would be necessary to produce any marked increase. In addition such amounts of radioactive material would present a definite health hazard.

3. Ionization is produced when the gas is heated to extremely high temperatures. This occurs naturally when the air ahead of a high hypersonic missile is rapidly decelerated through the bow shock wave that forms ahead of the body. (See Figs. 1 and 2.)

If the degree of ionization is insufficient at a given Mach number, it is possible that sime of these methods could be developed to increase the supply of electrons and ions.

The plasma contains free ions and electrons, so that when an electric field is impressed on the gas a current will begin to flow, as would be expected from dynamic theory. This is the case of the neon light, for instance, once the gas has been broken down by a high voltage source. The ionized gas behaves exactly like a conductor, when considered on a macroscopic scale; when it flows across a magnetic field a current is induced, and a force tending to slow down the motion of the gas is experienced. The dynamo equations for the solid conductor still apply. This is the fundamental idea behind the magnetohydrodynamic interaction, and it is simply an application of dynamo theory to conducting gases rather than to solid conductors.

The ponderomotive force must now be introduced into the hydrodynamic momentum equations as an additional body force, representing the coupling effect of the flow and the magnetic field.

In addition to the modification of the flow field, the flow interacts with the magnetic field and can modify it substantially. An electric field is induced normal to the magnetic field. The induced currents set up their own magnetic fields which modify the original pattern. This modified magnetic field in turn perturbs the modified flow field, and the process continues until equilibrium is attained. In most practical cases the perturbations in the original magnetic field will have negligible effect on the flow field.

The Pinch Process

Consider a tube containing a low pressure gas. (See Fig. 3.) If an electric field is applied across the two ends of the tube a current, initially confined to a thin skin at the outer diameter, will flow through the gas. This current gives rise to a magnetic field encircling the gas, and due to the pressure it exerts, the magnetic field squeezes the tube of gas so that its diameter contracts until there is equilibrium between the internal and magnetic pressures.

In this way the temperature of the gas is further increased, but the important fact is that the hot gases are no longer in contact with the wall. The magnetic field acts somewhat like a furnace liner in the tube, preventing the gas particles from contacting the wall.

One of the difficulties is that the plasma column can become unstable due to very small kinks. It may buckle like a structural column, or it may form a neck along its length. Stabilization can be achieved by:

1. Applying a longitudinal magnetic field inside the plasma and along its axis, which provides it with a "backbone."

2. Using the outer walls of the tube as the return path for the current, thus confining the magnetic field entirely within the tube.

By controlling the instability of a plasma, the pinch can be maintained for much longer periods. Recently reported results indicate that the British, with stabilization, have succeeded in raising a deuterium plasma to temperatures of 2,000,000 to 5,000,000 C while maintaining the pinch for a period of 0.002–0.005 sec. Previously the maximum temperatures achieved were of the order of 1,000,000 C

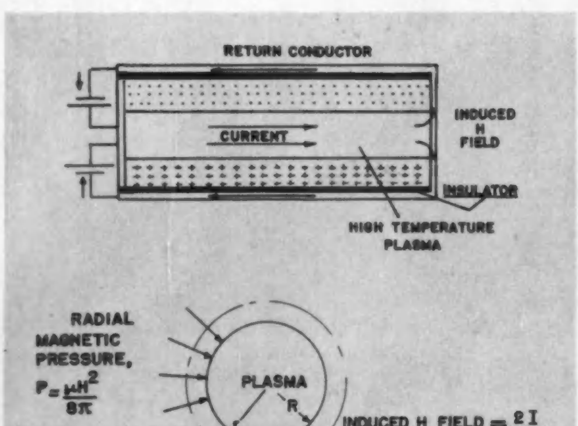


Fig. 3—Pinch effect, applied in fusion reactors and potentially useful in rocket engines, involves a tube containing a low pressure gas. An electric field is applied across the two ends of the tube. A current, initially confined to a thin skin at the outer diameter, will flow through the gas. This current gives rise to a magnetic field encircling the gas. Due to the pressure it exerts, the magnetic field squeezes the tube of gas so that its diameter contracts until there is equilibrium between the internal and magnetic pressures. Temperature of the gas is further increased, but the hot gases are no longer in contact with the wall.

with times of the order of 1 microsec. In a successful fusion reaction power will have to be generated in pulses lasting several seconds each.

Aerodynamic Applications at Republic

Behind the bow shock ahead of a re-entry missile traveling at Mach numbers of the order of 18, there is a cap of ionized air around the nose. It is well known that the aerodynamic heating which takes place in this vicinity has presented a serious problem. The question arose, in the light of the fundamental ideas on magnetohydrodynamics, whether a magnetic field could be applied at the nose to interact with this ionized region and possibly produce a reduction in the heating. At Republic we carried out a mathematical analysis of a simplified model, and the results were most encouraging. They indicated that even with low values of conductivity of about 2.5 mho/cm (corresponding to a Mach number of about 18), a reduction of the order of 28% in the heating rate, and 45% in the skin friction, might be expected with a magnetic field of 3000 gauss.

The interaction may be explained in non-mathematical terms as follows: On approaching the stagnation point, the flow divides symmetrically on either side of a zero streamline, and the velocity vector has two components, u and v, along and normal to the surface. (See Fig. 4.) At the wall, since the fluid is viscous and surface non-porous, these velocities are both zero. The magnetic field is applied normal to the surface and is assumed to be of constant strength H_ϕ. The magnetic field interacts only with the component of the velocity parallel to the surface, u. An electric field is set up and a current flows normal to both the magnetic lines and the u direction. A ponderomotive force, $\sigma\mu u H^2_\phi$ acts in the opposite direction to the velocity u and consequently tends to slow down the motion. Since this velocity u in a region close to the wall varies from zero at the wall to the inviscid flow velocity away from the wall due to the viscosity of the gas, the retarding force must also vary from zero at the wall to a uniform value in the inviscid flow. The interaction has two effects:

1. It reduces the velocity in the outside inviscid flow field. On this account the detachment distance between the shock and the body surface is increased.
2. The velocity profile in the viscous region close to the body surface is modified. The actual thickness of the "boundary layer" increases with increasing magnetic field strength.

Dimensionless velocity profiles show that the profile approaches more and more the shape associated with a turbulent boundary layer when the applied magnetic field is increased. This would lead one to believe that the magnetic field has the added effects of increasing the stability of the flow and delaying separation.

The analysis also indicates that the two effects listed above are equally important where shear is concerned. For heat transfer, however, the reduction is due mainly to the first, modifications in the dimensionless profile being relatively unimportant.

These results are, of course, theoretical and require experimental verification. At Republic, an experimental program has been put into effect to carry out such an investigation, and results should be forthcoming in the very near future.

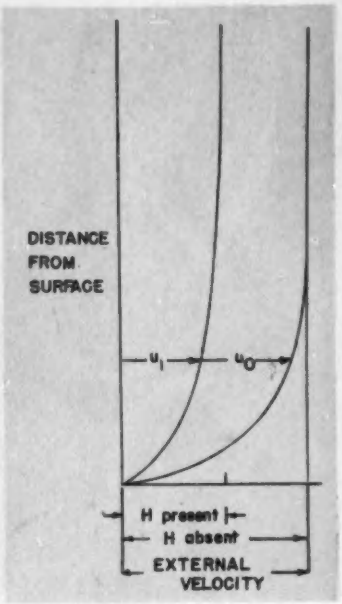


Fig. 4—Magnetic field (H) applied at nose might help keep nose cooler by increasing the distance between the shock and the body surface and by slowing the flow.

Circulating currents are present in the moving plasma due to the hydromagnetic interaction. The possibility arises of collecting this current and using it to partially regenerate the magnetic field described above. If this can be accomplished the weight of electrical equipment should be greatly reduced.

The Plasma Engine

Another phase of our investigations at Republic is the development of a plasma engine, in which small amounts of plasma are ejected at extremely high velocities. At the Naval Research Labs, for example, plasmas have been driven magnetically at speeds equivalent to Mach numbers in excess of 200. This type of engine seems to offer exceptional possibilities for flight in outer space. The drag at such altitudes is practically negligible and very little thrust is required to overcome it, either to maintain constant speed or to accelerate. In our opinion, this method is more favorable than the ion propulsion.

A number of basic aerodynamic studies would be very useful. It may be possible to generate lift and effect some method of control at extremely high altitudes. Delaying the onset of transition of a boundary layer from laminar to turbulent flow and preventing separation of flow at corners, would be extremely important contributions to the design of ultra high speed aerodynamic vehicles.

The pinch effect may find much the same application in rocket engines as it has found in the fusion reactor. It may then be possible to have engines working at temperatures far in excess of the limiting value for the materials being used in their construction. This would lead to the development of engines with very high efficiencies.

To Order Paper No. 39C . . .
. . . on which this article is based, turn to page 5.

SAE President William K. Creson (left) relates a humorous experience to Dr. John R. Dunning, Dean, School of Engineering, Columbia University (center) and Milton Kittler (right), Chairman, SAE Detroit Section. Dunning, guest speaker at the dinner, gave a talk entitled "Let's Meet the Communist Challenge!"

Passenger— Car

"A Look At Car Engineering Tomorrow" was the appropriate title selected for the SAE National Passenger Car, Body, and Materials Meeting held in Detroit, March 4–6. The meeting produced thought-provoking evidence to support the contention that automobile engineers are working more energetically than ever to produce better cars for tomorrow's transportation needs.

As one SAE member put it: "You can tell a lot about the automobile industry's progress — as well as its problems — by studying an SAE national meeting program.

It was pointed out, for example, that the growing prominence of the station wagon as a major body type is reflected in the session on station wagon styling and markets.

The station wagon market today is over a half million units, according to one speaker. Today's trend seems to be to divorce "wagons" completely from regular car lines. Some future possibilities: (1) a type similar to European rear-engine designs, (2) a pickup truck variation similar to the Ford Ranchero but with a removable or a canvas folding top. Unique, "club seating" arrangement may be tried. Station wagon buyers may also be offered sliding or roll top roofs and possibly "swing up" sides (for easy entrance and exit as well as accessibility). A "Transcontinental Cruiser" — with bunks, tables, built-in television, and cooking facilities — should not be ruled out, it was suggested.

Synthetic Ameripol SN rubber can be used interchangeably with natural tree rubber for making tires and other rubber products, SAE members were informed. Physically, the identity of the new synthetic material has been established by infrared spectra, phase microscopy, X-ray diffraction patterns, melting point, and second-order transition. More important, it vulcanizes the same, is reinforced by carbon black in the same manner, and gives cured properties almost identical to those obtained with Hevea rubber.

A tire's susceptibility to thump can be predicted from the difference frequency between diametrical and circular modes of vibration, as follows:

1. Less than 4 cps difference frequency will cause thumping only below 23 mph.

2. Between 4 and 7–8 cps can produce plainly audible thump between 20 and 35 mph.

3. From 8 to 10 cps will produce thump below 23 and a little above 35 mph, but somewhat less between 23 and 35 mph. Below 20 mph the exiting force is reasonably small and above 35 mph the masking noise is large enough to reduce the effect of thump noise.

4. Above 10 cps the frequency separation is large enough to make the sound or vibration waves add in a relatively disorganized manner which will sound more like roughness than thump.

The criterion for minimum thump is to have a shape and construction which do not permit the coincidence of the two natural frequencies with two revolution harmonics in the 20–35-mph speed range. This was substantially accomplished in 6.00–16 tires and partially gained in most new 14-in. tires.

Automotive engineers have found ways to investigate shake problems in the laboratory that save time and remove many of the uncertainties encountered in road testing. After determining the mode and frequency of the objectionable shake on the road, and the frequency of front and rear wheel movement, the same mode of shake is reproduced in the laboratory. Natural frequency of vibrations is then determined as well as the part of the structure which, by its distortion, is acting as the "spring" of the vibrating system.

Following engineering changes suggested by the laboratory studies, the reduction in shake is evaluated by observing ratings and amplitude measurements made on the road.

Two practical approaches to the

car engineers take a look at

Engineering Tomorrow

problem of improving passenger-car brakes without appreciably increasing costs have been found: (1) using mixed, asbestos-type lining materials, (2) using a combination of asbestos and semi-metallic materials.

A brake being tested, it was disclosed, uses conventional brake lining materials in which two 3-in. segments are replaced by bonded, sintered metallic material impregnated with powdered ceramics. Test data show these brakes are remarkably resistant to fading. While reducing fading, wear properties and other desired characteristics are retained. No significant change in brake size or design is necessary if such brakes are used.

Liquid-cooled brakes were reported to give greatly increased resistance to wear. Other advantages of liquid-cooled brakes are: (1) they would not be adversely affected by increased shrouding, (2) drum weight can be reduced, thereby decreasing unsprung weight. The extra cost of liquid-cooled brakes would be substantial, it was intimated.

New Engines

This year, Chrysler Corp. has introduced a new V-8 engine, versions of which are available in several models of the corporation's cars.

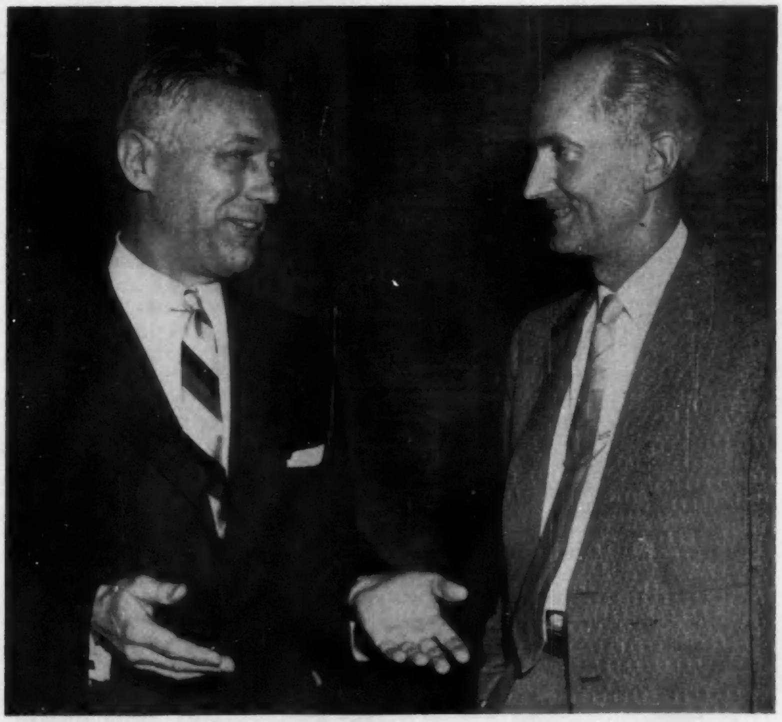
For greatest gains in weight reduction, a simpler light-weight head design was incorporated with the conventional wedge-shaped combustion chamber with side-by-side intake ports. This gave the desired weight reduction with minimum loss in power potential.

The new head design uses a simplified in-line valve arrangement and features coolant sections in the head without loss of effective cooling. Also, it permits use of the high exhaust manifolds necessary for installation ease.

The achieved weight decrease is important from a ride balance standpoint. It also improves fuel economy and manufacturing economy. The engine was designed as low as possible to enable a lowering of hoods.

American Motors has been developing its L-head and valve-in-head 6-cyl engines to take full advantage of recent improvements in the quality of regular-grade fuel. As a result, the compression ratio has been raised from 7.5/1 to 8.7/1 with subsequent increase in efficiency and nominal gain in power.

The chamber shape was altered by changing the shape of the piston top. This design change permitted the compression ratio



G. J. Huebner, Jr., General Chairman of the Meeting (left) with E. J. Premo, SAE Vice-President for Body Activity. Huebner also acted as toastmaster at the dinner.

SAE President William K. Creson (seated at the extreme right) enjoyed his get-together with the engineering educators shown here with him during the dinner at the meeting. They are, left to right, seated: Dean J. S. Johnson, College of Engineering, Wayne State University; Dr. John R. Dunning, Dean, School of Engineering, Columbia University; standing, G. R. Cowing, President, General Motors Institute; L. L. Henry, Dean of Engineering, Detroit Institute of Technology; S. S. Attwood, Acting Dean, College of Engineering, University of Michigan; Prof. W. H. Graves, University of Michigan.

Since assuming the Society's highest office, President Creson has visited with students and faculty from nearly a score of universities and colleges. His key program during '58 is students . . . how to bring a closer liaison between the Society and engineering students.

to be increased without appreciably increasing combustion roughness and with consequent improvement in efficiency.

High-speed movies of a head-on 52-mph crash showed the head of one of the dummy passengers sheared off clean, flying through the broken windshield. At the same time, the steering column was pushed upward until it could be seen above the top of the roof. Finally, there remained enough unabsorbed energy to cause the back wheels of both telescoped cars to rise what appeared to be at least a foot off the pavement.

The dummy subjects permitted determination of force systems for both restrained and unrestrained occupants. Elaborate systems of instrumentation made it possible to measure deceleration patterns for different locations on unit body and frame-type cars under severe impact.

The steel industry is making significant progress toward the solution of the troublesome aging problem that has long plagued automotive users of low carbon sheet steel, it was learned. Laboratory experimental work has established the mechanism which results in aging phenomena and necessary experimental work on commercial mills is now being undertaken. It has been demonstrated that all of the effects of aging can be eliminated by combined chemical and mechanical control, without the necessity of complete control of either. Prospects that nonaging steel can be produced commercially in the future are good, SAE members were told.

The automobile industry will use Chromallizing to an increasing extent in the near future, it was predicted. Chromallizing is a patented process for diffusing chromium (and other elements) into the surface of metal. As the chromium diffuses into the base metal, it combines with the elements present to form an alloy case that is resistant to wear, corrosion, and elevated temperatures. The process can be used on flat materials or on fabricated or machined parts. Present applications include gas broiler radiants, spark-plug electrodes, gas turbine parts, valves, cams, guides, and aircraft controls. Automobile mufflers are being made in England of Chromallized, low carbon steel and the manufacturer guarantees the mufflers, it was reported.

For many applications the tilt cab COE vehicle is significantly adaptable and economically advantageous. In support of this conclusion, the following factors are held to be paramount:

1. Revenue — A minimum BBC dimension enables increased cargo space within legal length and weight restrictions for tractor-trailer rigs, including sleepers and dromedaries, or straight trucks.

2. Safety — A high and forward driver position and increased windshield area provide utmost visibility. Specialized vehicle design can enable driver comfort features such as improved seating, ventilation, heating, and accessibility of controls and instruments, as well as ease of access to cab.

3. Maintenance — A rapid cab tilting arrangement, such as an electrohydraulic device, enables ready access to the engine compartment for routine inspection and servicing of the engine and accessory equipment. This feature minimizes delays enroute or during daily service checks and reduces the amount of chassis down-time during major overhaul operations.

Steelmaking capacity of 122 million tons annually by 1960 was predicted for Western Europe by an informed representative of the steel industry. From its peak production during World War II, U. S. has increased its steelmaking capacity 50%. During the same period, Western Europe increased its steel output 70% and Russia has made nearly a sixfold gain. U. S. capacity (1958) is 140 million tons compared with 56 millions tons for Russia (in 1957), it was disclosed.

About SAE Members

DR. KARL ARNSTEIN, who retired as vice-president in charge of engineering for Goodyear Aircraft Corp. in 1957, has been awarded the Navy Distinguished Public Service Award for his outstanding contribution to the Naval Establishment in the fields of scientific research and development.

Arnstein has made numerous contributions to aviation in general and U.S. Naval aviation in particular, which he still serves on a consulting basis. At Goodyear, he specialized in theory, design, and construction of aircraft and related structures.

A native of Czechoslovakia and graduate of the University of Prague, where he received a degree of Doctor of Technical Sciences, he turned to airship design in 1914. He came to the U. S. in 1924, and was actively associated with Goodyear until his retirement. Arnstein has served the National Advisory Committee for Aeronautics in the field of airships.

CARL L. SADLER, general manager of the Aviation Division, Sundstrand Machine Tool Co., has been elected vice-president in charge of the division.

JACK F. WOLFRAM, general manager of Oldsmobile Division and a vice-president of General Motors Corp., has been honored as Lansing's leading citizen of 1957 for his contributions to community leadership. He was presented with the Community Service Award of the Chamber of Commerce of Greater Lansing, Mich.

MARIO DiFEDERICO, former Akron factory manager of the Firestone Steel Products Co., has been appointed vice-president in charge of sales. He joined the company in 1947 and became Akron factory manager in 1954.

JAMES L. DOOLEY has been appointed vice-president, advance development, of McCulloch Motors Corp. He has been with McCulloch since 1951, and formerly was technical director of the company's Advance Development Division.

WILLIAM F. S. DOWLDING has been appointed director of quality control for Long Mfg. Division, Borg-Warner Corp. Formerly technical assistant to the president, he has served Long in engineering capacities for the past 24 years.

JAMES L. RYAN has recently been made vice-president of the Bucks Rental Co. of Philadelphia. Previously he was general manager for the company.

ROBERT M. CROMWELL, formerly development engineer for the Aircraft Products Division of Manning, Maxwell, & Moore, Inc., is now assistant project engineer, fuel controls, with the Hamilton Standard Division of United Aircraft Corp.

RICHARD D. PETERSEN, formerly junior chemical engineer, automotive research laboratory, American Oil Co. in Baltimore, Md., now holds a similar position with the company in Texas City, Tex., in the product quality group.

CLARENCE D. FOX, formerly development engineer for the Clinton Machine Co. in Iowa, is now an engineer in the Fuel Metering Division, Marvel-Schebler Products Division of Borg-Warner Corp. in Decatur, Ill.

HERMANN L. EBERTS, formerly president, Fleet Mfg., Ltd. in Ft. Erie, Ont., Can., is now manager, subcontract and procurement, Weapons Systems Division, R.C.A. Victor Co. Ltd. in Montreal.

EDWARD H. FISHER, formerly vice-president, Special Products Division, The Oliver Corp. in Chicago, is now the chief executive officer for the Tube Reducing Corp. in Wallington, N. J.

SAMUEL TARAN, JR., is now a design engineer for the Lockheed Missile Systems Division, Lockheed Aircraft Corp. Formerly he was a design engineer for the North American Aviation Missile Division, North American Aviation, Inc.

JOSEPH V. MILLER, formerly a design engineer for the Le Tourneau-Westinghouse Co. in Peoria, Ill., is now a project engineer for the J. I. Case Corp., Churubusco Division in Churubusco, Ind. His work includes the development and design of crawler tractor attachments and equipment.

H. T. MOORE has retired as president of the Tuthill Spring Co. He will continue to be active in the company in an advisory capacity.


Arnstein


Sadler


Wolfram


DiFederico


Dooley


Dowlding

Jepson

KARL H. JEPSON is now head of the electrical and accessories department group for Chevrolet. He has been with the division for 25 years and was assistant staff engineer in charge of accessories prior to his new position. Both Hansen and Jepson have been moved up to the status of staff engineer.

Eaton

E. E. EATON has been named to the newly-created post of director of engineering of Clark Equipment Co.'s Transmission Division. He has been with Clark for over 20 years and was chief engineer over both industrial and automotive sections prior to his new appointment.

O'Donnell

JOHN R. O'DONNELL has been appointed specialty sales manager of the American Bosch Division of American Bosch Arma Corp. He joined the Cleveland regional sales office of the corporation in 1953 and subsequently became manager of that office.

THOMAS J. KIELY, formerly field engineer, American Bosch Division, succeeds O'Donnell as manager of the Cleveland regional office. In his new capacity, he will have full responsibility for the sale and promotion of the Hydrotor hydraulic cranking system.

Musham

W. C. MUSHAM has been elected president and treasurer of the Imperial Brass Mfg. Co. of Chicago. He had been first vice-president of the company for the past nine years.

Rounds

ROBERT ROUNDS has been appointed works manager for the Schrader Division of Scovill Mfg. Co., Inc. Formerly plant superintendent, Rounds will be responsible for all U.S. manufacturing activities and branch technical liaison. He started with Schrader over 30 years ago as a product designer.

Brooks

GEORGE W. BROOKS, a former Navy commander, has been named to the newly created position of vice-president and general manager of Greer Hydraulics Engineering, Inc. Previous to his new position, he was executive assistant to the general manager of the Sargent Engineering Corp.

Weller

HARRY D. WELLER, JR. has been appointed regional manager of the White Motor Co. in charge of the Eastern Region which includes New England and the Eastern States down to North Carolina. He had been assistant regional manager since June, 1955.

K. STANLEY HAWKINS is now an industrial specialist with the Small Business Administration, a federal government agency. Among his duties as SBA representative in charge of the Columbus, Ohio, area, is the assistance of small business firms regarding technical problems and government procurements. Formerly he was supervising engineer with the Office of Inspector of Machinery, U.S. Navy Bureau of Ships.

KAI H. HANSEN has been made assistant director of the research and development department, Chevrolet Motor Division, General Motors Corp. Hansen had been with GMC since 1939, joined Chevrolet in 1952, and was assistant staff engineer prior to his new appointment.

FRANK B. GRAPER has been named manager of industrial account sales for the Standard Equipment Division, Dana Corp. He has been with the corporation since 1953 and was a sales engineer prior to his new appointment.

FREDERICK W. BURGIE has become general sales manager, Doehler-Jarvis Division of National Lead Co. Formerly he was assistant general sales manager for the division.

O. Mc INTYRE, formerly manager of sales engineering for the Norton Co. of Canada, has joined the Canadian Grinding Wheel Co., Ltd., as director and manager of its sales engineering department.

DR. C. S. DRAPER, director of the Instrumentation Laboratory at Massachusetts Institute of Technology, will be keynote speaker on the opening day of the Fourth National Flight Test Instrumentation Symposium, beginning May 5th at the Park Sheraton Hotel in New York City.

Hawkins

Hansen

Graper

Burgie

Mc Intyre

O. H. STELTER, JR., formerly sales engineer for Koenig Iron Works, Inc., in Houston, Tex., has become associated with the Holan Corp. of Georgia as manager of sales and sales engineering.

NORMAN B. CHRISTIE is now manager, vehicle planning section of the product/volume planning department of Chrysler Corp. Formerly he was assistant chief of section, technical information services, Engineering Division of Chrysler.

A. S. BARBER has become assistant co-ordinator for Waterloo College in Waterloo, Ont., Can. He is responsible for liaison between the college and cooperating companies. Waterloo has recently instituted the first co-operative engineering course in Canada. Barber was formerly in the sales department of National Carbon Co.

JACK HILLERY, senior superintendent of buildings and grounds for the University of California and chairman of awards for the Westwood Sertoma Club, presented a "Man of the Year" award to Dr. Joseph Kaplan, on February 6. Dr. Kaplan, UCLA physics professor, is chairman of the U.S. committee for the International Geophysical year.

FREDERICK C. FOSHAG is now project engineer for the Missile and Ordnance Systems Department, Aerosciences Laboratory of General Electric Co. in Philadelphia. At a later date he will serve as operational suitability engineer in the preliminary design and operations analysis group of the Nose Cone Section.

Formerly he was manager, engine test facilities, plant operation branch of ARO, Inc., in Tullahoma, Tenn.

MICHAEL J. TOMICH, formerly technical engineer with the Jet Engine Department of General Electric Co., is now technical engineer, Small Aircraft Engine Department, for the company in Lynn, Mass. His work includes the design and development of combustors and associated structures.

THEODORE M. ROBIE has become president of Eibor Services, Inc., Beloit, Wis., where he is engaged in consulting work, preparing technical articles on powerplants for advertising and publicity, and educational work. Formerly he was administrative engineer for Fairbanks, Morse & Co.

Robie was 1957 SAE vice-president representing Diesel Engine Activity, and was also Diesel Engine Activity Chairman for the Chicago Section in 1938–39.

Awards

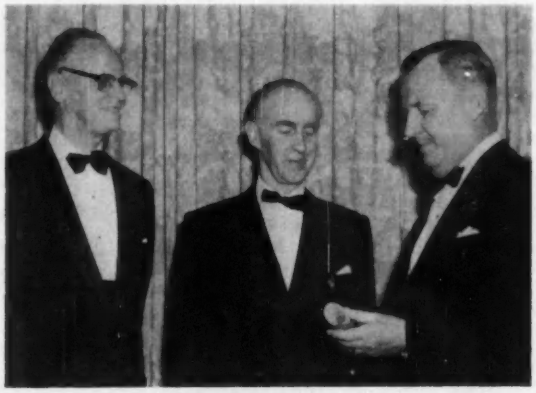
SAE Members were prominent among those who received awards at the Honors Night Dinner of the Institute of Aeronautical Sciences, on January 28 at the Hotel Sheraton Astor in New York.

WILLIAM LITTLEWOOD and BO K. LUNDBERG were named 1957 Honorary Fellows of IAS.

Littlewood, vice-president, equipment research, for American Airlines, Inc., is a past-president of SAE and has served as vice-president of both SAE and IAS.

Lundberg has been director of the Aeronautical Research Institute of Sweden, since 1948.

Fellowships in the IAS are awarded to "those who have attained a position of distinction in aeronautics and made notable and valuable contributions in one of the aeronautical sciences or aeronautical engineering." Among those named IAS Fellows for 1957 are: **LT.-GEN. LAURENCE C. CRAIGIE**, USAF (ret.), vice-president, American Machine and Foundry Co.; **ROY E. MARQUARDT**, president, Marquardt Aircraft Co., and **RAYMOND C. SEBOLD**, vice-president, engineering, Convair, (San Diego) Division, General Dynamics Corp.



Left to right: Arthur E. Raymond, winner of Guggenheim Medal for 1957; Bo K. Lundberg, IAS Honorary Fellow for 1957; Mundy I. Peale, 1957 IAS president.

The Daniel Guggenheim Medal for 1957 has gone to **ARTHUR E. RAYMOND**, IAS Honorary Fellow and past-president, and vice-president, engineering, Douglas Aircraft Co., Inc. He is a member of the NACA and the National Academy of Sciences.

Created in 1928 as an international award, the Guggenheim medal is given annually by the Daniel Guggenheim Medal Fund, Inc., to honor persons who make notable achievements in the advancement of aeronautics. The Medal is sponsored by three societies: the IAS, ASME, and SAE. Presentation was made this year at the IAS annual meeting.

The Royal Aeronautical Society Gold Medal, one of the world's most distinguished aviation honors, has been awarded to **JEROME HUNSAKER**, first IAS president. Professor Hunsaker, now Professor Emeritus, Massachusetts Institute of Technology, was instrumental in the founding of the first course in aeronautics in the U.S. at M.I.T. and was professor of aeronautical engineering there until his retirement in 1952. He was chairman of the NACA from 1941–46. Presentation of the award was at the IAS 26th annual meeting on January 28.

Stout

Smith

The old Ford Tri-Motor plane and its designer, the late **WILLIAM B. STOUT**, an SAE past-president, are to be honored in Dearborn by a state historical marker. On May 7, during Michigan Week, the marker will be dedicated near the historic former Ford Airport where many aviation "firsts" were achieved.

The double-marker will honor on one side the Ford Airport and the Tri-Motor, and on the other, Stout, the designer of the plane.

The committee on arrangements is comprised of representatives of the Dearborn Historical Commission, the State Historical Commission, the Ford Aerosports Club, the Aero Club of Michigan, the Ford Motor Co., the City of Dearborn, Chamber of Commerce, Dearborn Public Schools, and the Dearborn Inn.

BEN G. VAN ZEE has retired as chief engineer, product design, Minneapolis-Moline Co., and is living in Phoenix, Ariz.

He joined the engineering department of Minneapolis-Moline Power Implement Co. in 1930, and in 1936 was made assistant chief engineer. In 1944 he became chief engineer in charge of design on all tractors and industrial engines.

JAMES C. ZEDER, vice-president, engineering, — special advisor to the president of Chrysler Corp., and a past-president of SAE, will be one of the principal speakers at the Fifth Annual Conference for Engineers and Architects. The Conference, sponsored by the Ohio State University College of Engineering, is scheduled for Friday, May 2, on the campus.

Four SAE members have accepted an invitation from SAE member **FERNAND PICARD**, president des Sociétés d'Enginieurs et Techniciens de l'Automobile to become honorary members of the Comité de Patronage of the Seventh Congres Technique International de la Fédération Internationale. They are: **A. T. COLWELL**, vice-president, Thompson Products, Inc.; **PAUL C. ACKERMAN**, vice-president, director of engineering, Chrysler Corp.; **R. C. INGERSOLL**, chairman of the board, Borg-Warner Corp.; **E. S. MacPHERSON**, vice-president and adviser, engineering policy, Ford Motor Co.

continued on page 104

LAWRENCE H. SMITH will be in Wiesbaden, Germany for the next few months, setting up and training an engineering and manufacturing organization for The Leading Engineering & Mfg. Co. of Pontiac and its German partner, Stenzel & Co. While there, he will also work on a project for Adam Opel Division of General Motors Corp. Smith has been engaged in consulting work since relinquishment of his post as vice-president of engineering with General American Aerocoach Co.

FERGUSON J. BYARS, formerly sales engineer, Servomechanisms, Inc., Westbury, N. Y., is now senior sales engineer, electronics department of Hamilton Standard Division, United Aircraft Corp., in Broad Brook, Conn.

ROBERT E. ZULEGER has been appointed assistant sales manager in the Automotive Division of A. O. Smith Corp. Formerly he was assistant chief product engineer with the corporation.

STANLEY F. LINDQUIST, formerly coordinating engineer with the Automotive Division, is now an account executive.

GERALD J. KUCHERA, formerly with the division as coordinating engineer, trucks, has become an account executive.

SAE Members Say:

MALCOLM P. FERGUSON, president, Bendix Aviation Corp, . . .

"Automation is as important to a hospital, bank, or insurance company as it is to a guided missile plant or automobile line," stated Ferguson. Automation doesn't produce unemployment, he said, citing doubled employment in the nation's most "automated" industries as a result of larger markets to be served. He added that "judgment, appraisal, and imagination still belong exclusively to human beings."

HENRY DREYFUSS, industrial designer . . .

'Products will become functionally obsolete so fast that it will seem absurd to make them stylistically obsolete," Dreyfuss cautioned. He branded as "unsound business" the transforming of last year's model into this year's model by the addition of a tail fin or similar external decoration.

Products become obsolete almost as they leave the drawing board, as in the aircraft industry, making "planned obsolescence" ridiculous. Meeting this situation, many corporations have removed outstanding people from their normal positions to give them the opportunity to take the broad view of things and release creative imagination from daily problems.

Obituaries

WALTER E. ARENS . . . (M'55) . . . assistant engineer with P&H Diesel Engine Division of the Harnischfeger Corp. . . . he had been with the corporation since 1952 . . . died Dec. 7 . . . born 1925 . . .

JAMES R. McCLELLAND . . . (M'56) . . . industrial sales representative for Ontario Marketing Division of Imperial Oil Ltd. . . . joined the company in 1930 . . . died Nov. 8 . . . born, Scotland, 1900 . . .

THORSTEN Y. OLSEN . . . (M'11) chairman of the board, Tinius Olsen Testing Machine Co. . . . joined the company in 1903 . . . retired as president of the company in 1955 . . . died Dec. 10 . . . born 1879 . . .

L. T. HILL . . . (A'50) . . . manager of lubricants department, Shell Oil Co. of Canada, Ltd., Toronto . . . joined Shell in 1930 . . . died Jan. 25 . . . born, Toronto, 1909 . . .

CECIL H. TAYLOR . . . (M'08) . . . consulting engineer with Roy S. Sanford and Co. for the past eight years . . . formerly with the Bendix Aviation Corp. . . . died Feb. 8 . . . born 1878 . . .

TIBOR UNGAR . . . (M'52) . . . chief development engineer, Kirkhill Rubber Co. . . . joined company in 1953 . . . formerly senior design engineer with Consolidated Vultee Co. . . . died Dec. 25 . . . born, Czechoslovakia, 1911 . . .

FRANK G. WOOLLARD . . . (M'16) consulting engineer in Birmingham, England . . . pioneered adoption of first large scale attempts at continuous production in Britain . . . became director of Birmingham Aluminum Casting Co. Ltd. and Midland Motor Cylinder Co. Ltd., in 1936 . . . died Dec. 22 . . . born, England, 1883 . . .

Rambling . . .

THROUGH THE SECTIONS

TOMORROW'S **Space Pilot** will have to fly a narrow speed channel through the sky to avoid self-destruction . . . stated K. E. Van Every of Douglas Aircraft at **SOUTHERN CALIFORNIA SECTION** February 10. Boundaries of this "corridor of continuous flight"—he related—are dictated by aircraft lift requirements and structural heating limitations. The former imposes a minimum on speed a pilot must fly to maintain level or climbing flight, while the latter is a temperature problem restricting his maximum speed.

. . .

In 15 minutes, **one man with a power chain saw** can do as much work as two lumberjacks can do with a cross cut saw in two or three hours, says W. B. Burkett of McCulloch Motors (**SALT LAKE CITY GROUP** in January) . . .

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IHC's Merrill Bennett (At South Bay Division, **NORTHERN CALIFORNIA SECTION**, February 4) envisioned tomorrow's tractor operator as comfortably ensconced in an air-conditioned cab with control-tower visibility. This **farmer of the future**, according to Bennet, won't need big muscles to control his giant powerplant—'cause power systems will furnish needed controlling forces . . .

. . .

A new group of additives must be added to those already available to meet the requirements of tomorrow's higher octane fuels, according to DuPont's Paul E. Richards at **ST. LOUIS SECTION** in January.

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Earthmoving jobs done today cost approximately the same per cu yd (40¢ vs 35¢) as in 1929—even though wages have tripled or quadrupled—stated Don Graham of GMC's Euclid Division (**MID-CONTINENT SECTION**, February 3) . . . Moving a 150 ton derrick over 100 miles of Saudi-Arabian sand on tires 9 ft in diameter and 3 ft across was demonstrated and explained at the Mid-Michigan meeting, via a movie and W. E. Ring of Arabian-American Oil Co. (Aramco) . . .

. . .

THREE SIMULTANEOUS SESSIONS were staged, for the first time, at **METROPOLITAN SECTION** February 11. Co-sponsored by the six Section Activity Committees, afternoon sessions and dinner meetings drew over 300 members and guests.

Distinguished participants included, left to right, T. B. Rendel, meeting general chairman; Chancellor Clifford C. Furnas, University of Buffalo and dinner speaker; 1958 SAE President W. K. Creson; John A. C. Warner, SAE secretary and general manager; and R. M. Cokinda, Section chairman.

"In general, the commercial airlines have introduced aircraft into service 15 to 20 years after research aircraft have flown with the higher capabilities. A research airplane flew 1200 mph in 1950. **I would predict that commercial airlines** would equal or better this speed in their services by 1963–65," forecasted GE's James J. Bingham on January 21, **MID-CONTINENT SECTION.**

. . .

Final design statistics of Dana Corp.'s **new 12-speed truck transmission** were revealed in February at **NORTHWEST SECTION** and **COLORADO GROUP.** The following conclusions were explained:

TARGET	RESULT
Capacity for heavy duty	—700 ft lb nominal
Light weight	—600 lb
Conventional application	—yes
Short length	—31 in.
More than 8 speeds	—12 speeds
Over 9 to 1 ratio spread	—13.1 to 1
Less than 1.30 step at the top	—1.26
Conventional control	—single lever
Familiar maintenance	—yes — countershaft design
Synchronized shifts	—yes
Power shifts	—yes
Gear hopping guards	—yes

Dana's E. J. Barth and K. E. Pyle made the presentations . . . a digest of which will appear in a future issue.

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GIANT STEPS in the development of the automobile was the subject of **PITTSBURGH SECTION'S** recently completed TV series entitled "Your Car." The 19 well-received successful programs featured an expert for each show.

The series was originally conceived by Murray Fahnestock who, with Court Wolfe of Mellon Institute of Industrial Research, secured WQED—a local educational TV station—for the weekly series.

The Section TV Committee's ex-

pressed purpose was to educate the general public in treatment and use of its cars . . . to create interest in the Society, and in the automotive industry among people of high school age.

As host for the Series, SAE Past-President R. J. S. Pigott opened each program, introduced the speakers and their topics. As coordinator for the Series, Murray Fahnestock's responsibilities included maintaining liaison between WQED and the speakers, seeing that each program started on time, and arranging for substitute programs when necessary.

Mechanically, while part of the first program was done outdoors, most were shown with a living-room background . . . however the planners now feel that an actual car and simulated garage background would be most effective.

Publicity for the Series included a regular listing in newspapers, TV Guide, and schedule listing in Pittsburgh's technical calendar. In addition, releases were mailed by WQED to its mailing list of 400. Specific attention was called to SAE during the first 30 seconds of each show, when "Society of Automotive Engineers, Pittsburgh Section" was shown on the bottom of the screen . . . monthly technical Section meetings were announced by Host Pigott.

There were approximately two million people in the WQED territory, and while rough view checks suggest that one out of 100 may have watched, with an estimate of one out of 1000, the Section had an audience of 2000.

. . .

Rambling . . .

THROUGH THE

1958 SAE PRESIDENT

W. K. CRESON'S dedication to students has been well exemplified in his recent trips to Sections in Canada and the U.S. Talking with students and professors, Creson has told his own story on what SAE participation can mean to students, and SAE's role in an automotive engineer's career.

Other highlights of his trips have included being presented with Section mementos such as a carved French-Canadian peasant figurine, cane umbrella, and letter opener . . . as well as making presentations himself.

(Above Creson, left, appears with Montreal Section Chairman J. T. Dyment, after receiving the peasant figurine. Dyment also serves as vice-chairman of the Overseas Information Advisory Committee.)

Certificates of Membership presentations have been part of the presidential touring . . . below he is shown with members of the **PHILADELPHIA SECTION**, on February 12, after presenting Edwin H. Godfrey, consulting engineer, a 25-year Certificate. Left to right are: Section Chairman M. A. Hutelmyer; E. H. Godfrey; W. K. Creson; and speaker of the meeting, J. R. Rowell, "Effect of Dirt on Engines" was the title of Rowell's presentation.

"METALLURGICAL MEANDERING"

through the need for greater cooperation between the metallurgist and the engineer was covered at **WESTERN MICHIGAN SECTION** February 4. Speaker D. A. Paull, Sealed Power Corp., stressed a need for standardization and improvements of cast metal specifications, especially for cast iron. Left to right: Section Technical Chairman W. C. Chaffee, and D. A. Paull.

Right at **CLEVELAND SECTION'S** January meeting, Creson visits with, left to right, Section Chairman E. J. Manganiello; Speaker D. F. Caris of GMC's Research Staff, power development section; F. J. Sanders, speaker's sponsor; and W. K. Creson.

SECTIONS

SPEAKER W. D. Schwab of Cummins Engine Co. making his presentation on Cummins turbocharged diesel engines before the **MILWAUKEE SECTION** on February 7.

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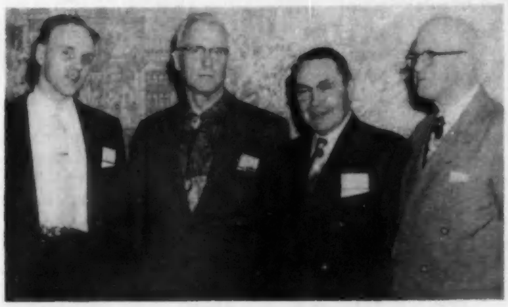
L. P. SAUNDERS received a 35-year Certificate of Membership at the February 4 meeting of **NORTHERN CALIFORNIA SECTION'S** South Bay Division. Left to right are: W. A. Casler, Division chairman; L. P. Saunders; Nicholas Buchanan, chairman of the Northern California Section; and C. G. A. Rosen, SAE past-president.



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PROGRESS MADE in automotive fuels, along with developments in automotive engines, were discussed February 11 at the **MOHAWK-HUDSON SECTION.** Gathered around the rostrum are, left to right, J. B. James, Section vice-chairman; P. E. Kezer, Section chairman; D. L. Berry, speaker from Shell Oil Co.; and J. P. Thomas, Section treasurer.

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THE EDSEL and its various phases were discussed February 12 at **TWIN CITY SECTION** by Ford's W. E. Burnett. Above is Speaker Burnett (left) and Section Vice-Chairman A. L. Preston. This paper, which appeared on pages 69–71 of the February Journal, will appear in full in 1958 SAE Transactions.

COMEDIAN AL MACK was master of ceremonies at a variety show January 21 at **ST. LOUIS SECTION'S** Ladies' Night. Mack, left, is greeted by Section Chairman W. E. Williamson.

A small portion of guests attending the Section party included, left to right, Mrs. and Mr. Guy A. Turner, Jr.; Mrs. and Mr. M. D. Younger; and Mr. and Mrs. A. L. Heintze.

ABOUT SAE MEMBERS

continued from page 100

ROBERT CURCURU has been made vice-president to head the Research and Design Division, Jim Robbins Co., Hazel Park, Mich. Formerly Curcuru served as general manager of the same division.

L. P. DICKEY, formerly zone manager, Moline, Ill., New Departure Division, General Motors Corp., is now district sales manager, Reed Instrument Bearing Co., Los Angeles, Calif.

L. E. DRUM, formerly manager of the Springfield, Ohio, works, Motor Truck Division, International Harvester Co., has become manager of the Indianapolis works of the company.

EMIL O. WIRTH has been named general factory manager, Bendix Products Division, Bendix Aviation Corp., South Bend, Ind. He has been on the management staff and was formerly manufacturing manager, aircraft wheels and brakes section, and coordinator of the Bendix fuel injection program.

JACK E. MARTENS, formerly principal senior design engineer, Ford Motor Co., is now director of engineering, the Anderson Co., in Gary, Ind. His work includes research and development of the "Roton" anti-friction linear actuator for automotive and allied applications.

J. W. JASPERSEN, vice-president and director of sales for the Walker Mfg. Co., has been elected to the board of directors of the company.

WAYNE H. MacFARLANE, vice-president, administration, for Minneapolis-Moline Co., has been elected a director of the company.

C. J. REESE, president of Continental Motors Corp., has been appointed to the Industry Consulting Committee of the National Advisory Committee for Aeronautics.

The Private Truck Council of America elected the following officers at its 19th Annual Convention on January 30:

HARRY O. MATHEWS, Armour & Co., chairman of the board; Directors for 1958, elected for three-year terms: **O. A. BROUER**, Swift & Co.; **A. H. KREUDER**, Wilson & Co.; **T. A. DRESCHER**, Milk Industry Foundation; **HENRY ROWOLD**, Mack Trucks, Inc.; **R. L. FRANCIS**, Esso Standard Oil Co. **B. E. ROGERS**, Richfield Oil Co., was among those elected for one year terms.

JOHN G. STRAND has retired as lubrication engineer, automotive, for the Texas Co. He had been with the company for 29 years.

SAE SECTION

BRITISH COLUMBIA

April 21 . . . Aviation meeting sponsored by Canadian Pacific Airlines at Vancouver's International Airport.

CENTRAL ILLINOIS

April 15 and 16 . . . 9th Earthmoving Industry Conference. Pere Marquette Hotel, Peoria, Illinois. See opposite.

CLEVELAND

April 15 . . . Dr. E. S. Rowland, chief metallurgist, Timken Roller Bearing Co. "Residual Stresses." The Sheraton-Mayflower Hotel.

DETROIT

April 21 . . . E. C. Quinn, president, Chrysler Division, Chrysler Corp. "Look What You've Started." Commodore Perry Hotel, Toledo, Ohio. Special Feature: Tour of Ford Motor Co., Hardware Division Plant, Monroe, Mich.

April 28 . . . Field Trip — Tour of Lincoln Assembly Plant, Ford Motor Co., Wixon, Mich. SAE members only. No dinner.

May 5 . . . William M. Schmidt, Chrysler Corp., H. W. Johnson, Ford Motor Co., P. O. Johnson, Fisher Body Division, GMC. "What Price Lowness?" Dinner 6:30 p.m. Meeting 8:00 p.m. Dinner Speaker: Herbert S. Ruben, Merrill-Lynch-Pierce-Fenner & Beane.

INDIANA

April 17 . . . Student Meeting. Bart Cotter, chief engineer, Fisher Body Division, GMC. "Automotive Styling." Purdue University, Lafayette, Ind. Dinner 7:00 p.m. Meeting 8:00 p.m. Special Feature: Inspection Tour, Purdue Rocket Laboratory. Student Award, Fisher Body Craftsman's Guild. Time 4:00 p.m.

KANSAS CITY

April 24 . . . Major Gen. Marvin Demler, deputy commander, A.R.D.C. "The Guided Missile." World War II Memorial Building, Linwood and Paseo, Kansas City, Mo. Dinner 7:00 p.m. Meeting 8:00 p.m.

METROPOLITAN

April 17 . . . Thursday Luncheon. Speaker to be a representative from Rootes Motors. Roger Smith Hotel, Lexington Ave. & 47th St., New York City. Time: 12:00 Noon.

April 24 . . . Passenger Car & Body Activity Meeting. Max Tauschek, chief engineer, Valve Division, Thompson Products Co. "Valves and Valve Components." Henry Hudson Hotel, 57th St. & Ninth Ave., New York City. Meeting 7:45 p.m.

May 8 . . . Aeronautics Dinner Meeting. Joe Dressel, director of airborne equipment, Bureau of Aeronautics. "Ground Level Escape Possibilities in Military Aircraft." Brass Rail Restaurant, Fifth Ave. & 43rd St., New York City. Cocktails 5:30 p.m. Dinner 6:30 p.m. Meeting 7:45 p.m.

MID-MICHIGAN

May 5 . . . Ann Landers, columnist. "Human Engineering." Bancroft Hotel, Saginaw, Mich. Dinner 7:00 p.m. Meeting 8:00 p.m. Special Feature: Ladies Night.

MILWAUKEE

May 2 . . . Plant Trip. Evinrude Motors Plant #1 and Plant #2. Meeting to be held at the Milwaukee Athletic Club, 758 N. Broadway.

MONTREAL

April 21 . . . P. M. Krawchuk, technical services, Imperial Oil Ltd., Toronto, Ont., Canada. "Residual Fuels — Diesel Engines." Sheraton-Mount Royal Hotel. Dinner 7:00 p.m. Meeting 7:45 p.m.

NEW ENGLAND

May 6 . . . Robert F. Lybek, retired, Esso Standard Oil Co. "Fast Trip to the Moon." M.I.T. Faculty Club, Cambridge, Mass. Dinner 6.45 p.m. Meeting 8:00 p.m. Special Feature: Colored Movies — Jet Engines.

NORTHERN CALIFORNIA

April 23 . . . D. M. Severy, J. H. Mathewson, A. W. Siegel, Institute of Transportation & Traffic Engineering, University of California. "Automobile Head-On Collisions Series 11." Engineer's Club, 206 Sansome St., San Francisco. Dinner 6:30 p.m. Meeting 8:00 p.m.

MEETINGS

OREGON

April 24 . . . W. F. Le Fevre, engineer, Freightliner Corp. "Problems of Vehicle Ride." Imperial Hotel, Portland. Dinner 7:00 p.m. Meeting 8:00 p.m.

PHILADELPHIA

May 9 . . . Ladies Night, Springhaven Country Club. Dinner 6:30 p.m. Meeting 7:45 p.m.

PITTSBURGH

April 14 . . . Annual Section Student Meeting. Student Paper Competition. Special Guest: SAE President William K. Creson. "Tomorrow's Engineer." Mellon Institute, Pittsburgh. Dinner 6:30 p.m. Meeting 8:00 p.m.

SOUTHERN CALIFORNIA

April 14 . . . A. B. Hirtreiter, chief engineer, automotive suspension department, Goodyear Tire & Rubber Co. "Air Springs — From Jounce to Rebound." Rodger Young Auditorium, 936 W. Washington Blvd., Los Angeles. Dinner 6:30 p.m. Meeting 8:00 p.m.

SPOKANE INTERMOUNTAIN

April 15 . . . Lee Ketchum, Lee Ketchum Mfg. Rep., "Vapor Phase Cooling of Air Brakes." Desert Caravan Inn, Spokane. Social Hour 6:30 p.m. Dinner 7:00 p.m. Meeting 8:00 p.m.

TWIN CITY

May 9 . . . Ladies Night. Dinner Dance.
April 17 . . . W. V. Buck, regional engineer, Bureau of Public Roads, Minn. Gene S. Hart, senior field engineer, Le Tourneau-Westinghouse Co., Peoria. "Panel Discussion on Federal Road Program." Special Guest: SAE President William K. Creson. Hasty Tasty Restaurant, 1433 W. Lake St., Minneapolis. Dinner 6:45 p.m. Meeting 8:00 p.m.

WASHINGTON

April 18 . . . Martyn V. Clark, assistant chief of technical division, CAA, Washington, D.C. "Accident Investigation Procedures." Occidental Restraurant, Pennsylvania Ave., Washington, D.C. Dinner 7:00 p.m. Meeting 8:00 p.m.

SAE Central Illinois Section's 9th Annual

Earthmoving Industry Conference

April 15-16, 1958 Pere Marquette Hotel, Peoria, Ill.

Tuesday, April 15
8:00 a.m. — Registration — Pere Marquette Hotel
9:30 a.m. — Madison Theatre
Welcome .... **Karl L. Mason**, Chairman of Conference
Invocation .... **Rev. Howard B. Detweiler**, Glen Oak Christian Church

Keynote Speaker .... **Col. James H. Frier**, Consulting Engineer, Emerich Consulting Co.
"Plan It — Do It, and Win"

Technical Chairman — **T. L. Burcham**, Caterpillar Tractor Co.

"Contractor's Approach to Design"
D. A. Armstrong, S. J. Groves & Sons Co.

1:30 p.m. — Madison Theatre
Technical Chairman — **T. E. Hrodey**, Caterpillar Tractor Co.
"Single or Multi-Engine Power Plants for Off-Highway Equipment"
Ken Leech, Cummins Engine Co.

"Basic Hydraulic Design Considerations"
Morton M. Coker, Caterpillar Tractor Co.

5:30 p.m. — Social Hour — Mezzanine — Pere Marquette Hotel

6:30 p.m. — **E. I. C. Annual Banquet** — Ballroom, Pere Marquette Hotel

Toastmaster .... **George W. Eger**, Chairman, Central Illinois Section

Dinner Speaker .... **Countess Maria Pulaski**
"My Life as a Spy"

Wednesday, April 16
9:00 a.m. — Madison Theatre
Technician Chairman — **D. K. Heiple**, LeTourneau-Westinghouse Co.

"Excavator Economics in Earthmoving"
E. O. Martinson, Koehring Co.
Ralph Kress, LeTourneau-Westinghouse Co.

"Fabrication of High Strength Alloy Steels"
K. F. Schauwecker, U. S. Steel Corp.
S. C. Lore, U. S. Steel Corp.

1:30 p.m. — Madison Theatre
Technical Chairman — **J. T. Liggett**, Allis-Chalmers Mfg. Co.

"How Performance Factors Affect Transmission Design"
E. A. Richards, Rockford Clutch Division, Borg-Warner Corp.

"Contractor Versatility with Construction Machinery"
Henry T. Perez, Construction Methods & Equipment Magazine

"Deep Freeze Up-to-Date"
Cdr. H. W. Whitney, Civil Engineering Corps, U. S. Naval Reserve

Co-Authors Matzdorff and Newberry Selected for Manly Memorial Award

R. E. Matzdorff and C. F. Newberry, both of Marquardt Aircraft Co., have been selected to receive the 1957 Manly Memorial Award for their paper entitled "Requirements, Parameters, and Design Considerations for Pneumatic Inlet Control Systems."

Medals will be presented on behalf of SAE by Raymond W. Young, chairman of the Manly Memorial Board of Award, at a luncheon in New York City's Hotel Commodore, April 10, during the SAE National Aeronautic Meeting.

Matzdorff Newberry

Matzdorff, presently manager of the aerothermodynamics department, controls and accessories subdivision, Marquardt Aircraft Co., attended California Institute of Technology, receiving a BS in Mechanical Engineering, MS in Aeronautical Engineering, and professional Engineering Degree in Aerodynamics. Prior to joining Marquardt in 1956, he served with Convair in Ft. Worth, Tex.

Newberry was graduated from the University of Kansas with a BS Degree, and is presently studying for a MA Degree at UCLA. He joined Marquardt in 1951, served with American Helicopter in 1953 as powerplant analyst, then rejoined Marquardt in 1954. Newberry is presently project engineer, inlet controls, Controls and Accessories Division.

The Manly Award honors the author, or authors, of the "best paper relating to the theory or practice in the design or construction of, or research on, aeronautic powerplants or their parts or accessories which shall have been presented at a meeting of the Society or any of its Sections during the calendar year."

Matzdorff and Newberry presented their paper at the SAE Aeronautic Meeting on Oct. 4, 1957, in Los Angeles. It will appear in full in 1958 SAE Transactions.

This is my slide rule.
There are many like it but this one is mine.
My slide rule is my friend.
And I shall learn to love it as a friend.
I will obey my slide rule.
When my stick tells me that 5 × 5 is 24.8,
Then, by God, five times five is twenty four point eight.
I will learn the anatomy of my slide rule,
Though I die in the struggle, I will use faithfully every scale.
The black scale and the red,
The inverted C and the inside out log.
The reversed A and the mutilated D.
I will master them all, and they will serve me well, they will!
I will cherish my slipstick and never shall
profanity sear its long, graceful mahogany limbs.
My slide rule shall be my brother in suffering.
Through long hours of midnight toil
We will work together, my slide rule and I.
And on the great day when my slide rule and I
have finished our appointed task and the problem
is done and the answers are right,
I will take that damn stick and have one hell of a fire I will!

* * * * *

Note to liberal arts students: A slide rule is not a baseball regulation.

Printed at the request of Henry Marzullo, Jr., former chairman of the SAE Student Branch at the City College of New York. Courtesy of CCNY Vector.

Council, Tech Board to Be Posted on CRC Progress

COORDINATING Research Council activities will be reported annually to the SAE Council and Technical Board by SAE members of the CRC Board of Directors. Closer communication between the CRC and SAE policy-making groups was favored at an informal meeting held during Annual Meeting in January.

The meeting was attended by CRC Directors Arthur Nutt, G. J. Huebner, Jr., R. F. Kohr, H. F. Barr, and D. D. Streid. Also present were W. Paul Eddy, 1957 SAE President; William K. Creson, 1958 SAE President; SAE Past President G. A. Delaney; O. K. Kelley, Chairman of the 1958 Technical Board; and SAE staff members John A. C. Warner, Joseph Gilbert, M. L. Stoner, and Dora Cella.

SAE 1958 National Meetings

- **April 8-11**
Aeronautic Meeting, Aeronautic Production Forum, and Aircraft Engineering Display, Hotel Commodore, N. Y., N. Y.

- **June 8-13**
Summer Meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

- **August 11-14,**
West Coast Meeting, Ambassador, Los Angeles, Calif.

- **September 8-11,**
Farm, Construction and Industrial Machinery, Production Forum, and Engineering Display, Milwaukee Auditorium, Milwaukee, Wis.

- **September 29-October 3**
Aeronautic Meeting, Aircraft Production Forum, and Engineering Display, Ambassador, Los Angeles, Calif.

- **October 21-24**
Diesel Engine Meeting, Lord Baltimore Hotel, Baltimore, Md.

- **October 20-23**
Transportation Meeting, Lord Baltimore Hotel, Baltimore, Md.

- **November 5-6**
Fuel and Lubricants Meeting, The Mayo, Tulsa, Okla.

Coverage Expanded in SAE's Helical and Spiral Spring Manual

A REVISED edition of the Manual on Design and Application of Helical and Spiral Springs is now available from SAE as Technical Report 9. It gives a concise account of the essentials involved in the design and application of helical and spiral springs. The document also promotes an appreciation of the nature of spring problems and serves as a guide for the following:

Designers will find production methods for raw materials as well as for springs themselves.

Production Men will better understand the need for tolerances and other requirements expressed on spring drawings.

Spring Users are provided with practical information which will aid their battle for cheaper, safer springs. Designs which are incompatible with spring theory are explained.

The new manual is more complete than the old one, which was last revised in 1945. Areas which are greatly expanded include: residual stresses, particularly as affected by shotpeening and presetting; dynamic loading and surge wave theory; buckling of springs as related to new elastic theories; fatigue durability; flat spiral springs and motor springs; hot coiled springs; surface protection afforded by various types of plating; and tolerances for the manufacturer.

TR-9 was revised by the SAE Spring Committee under the direction of H. H. Clark, chairman, and Bernhard Sterne, vice-chairman. It is available from SAE Special Publications Department, 485 Lexington Ave., New York 17, N. Y. Price: $4 to members; $8 to nonmembers.

'Artificial Feel' Studied By Flight Control Group

LATEST data on artificial feel systems are being coordinated by members of Committee A-18, Flight Control System. The committee is seeking information on both longitudinal and lateral channels as related to:

- A system schematic showing approximate linkage ratios
- Feel spring characteristics (breakout and gradient)
- Normal and pitching acceleration bobweight gradients
- Viscous damper gradient
- Designed non-linear, ratio change, and "Q" spring characteristics
- System friction level
- Range of airplane "g" per degree surface, roll rate per degree surface, short period natural frequency and damping ratios
- Use of roll and pitch stability augmentation

Results of the study will be reported at the next A-18 meeting. At that time the committee will decide whether such information would be suitable as a new aeronautical recommended practice.

At its organizational meeting last January where the artificial feel system project was initiated, A-18 dedicated itself to speeding up the research and development of flight control systems. All aspects of flight control associated with aircraft, missiles, and space vehicles will be encompassed. The committee will study inputs such as human pilot or sensors measuring airframe flight parameters, and self contained guidance or remote control systems. Output has been defined as control of the aircraft's flight path.

New High-Strength Bolt Materials Fatigue Tested at 1200-1650 F

Four new high-strength bolt materials are being fatigue tested at 1200-1650 F to establish suitability for use in aircraft engines. AMS 5735, Inconel 901, Udimet 500, and Inconel 700 were selected by members of E-25's Subcommittee on Fatigue Testing at Elevated Temperatures. (l. to r.) E. F. Gowan, D. H. Secord, H. A. McFarland, A. C. Johnson, Chairman V. E. Newman, T. C. Baumgartner, Gustaf Carvelli, R. F. Schwarzwalder.

Hydrant Fueling Creates Surge Pressure Problems

SURGE pressures in new hydrant fueling systems for aircraft have raised two questions: (1) What should the closure time be for level control valves *if* spillage and pressure damage to the inlet valve are to be avoided? (2) What should the maximum total pressure on the inlet side of the level control valve be *before* hydrant shutdown?

A new panel of SAE Committee A-16, Aircraft Fuel and Oil Systems and Equipment, is currently looking into these problems, which stem from the following:

- Fuel lines, formerly 100–200 ft for tanker trucks, are now 3000–6000 ft of pipeline.
- Previously, fuel was delivered at 200 gpm. This figure has jumped to 300–600 gpm at pressures up to 90 psi.

Technishorts . . .

BERNHARD STERNE, Chrysler Corp., has been appointed chairman of the SAE Spring Committee for 1958. He succeeds H. H. Clark, Eaton Mfg. Co., who will be 1958 vice-chairman. The committee is currently revising the Leaf Spring Manual. (See p. 107 for story on new Manual on Design and Application of Helical and Spiral Springs.)

RALPH BERTSCHE, GMC Truck and Coach Division, and **DON BLANCHARD,** SAE, attended the March 10–14 Geneva, Switzerland meeting of the Working Party on the Construction of Vehicles of the Subcommittee on Inland Transportation of the Inland Transport Committee of the Economic Commission of Europe. They were industry members of the U. S. State Department Delegation to the meeting.

P. G. BELITSOS, chairman of the SAE Aeronautical - Automotive Drawing Standards Committee, will speak on the "Maximum Material Concept Applied to Tolerancing of Form and Position" at a University of Illinois seminar. The *New American Drawing Standard* is the theme of the April 29–30 meeting. Mr. Belitsos, who is supervisor of standards engineering at General Electric's Aircraft Gas Turbine Division, will be one of seven speakers.

THE GASOLINE ENGINE TEST CODE is being broadened to encompass other spark-ignition engines, each requiring different fuels. Revisions are being made by a new Engine Committee subcommittee, which expects to work closely with the Diesel Engine Test Code Subcommittee to insure compatibility.

A TEST CODE FOR TURBOSUPERCHARGER PERFORMANCE is slated for development by a subcommittee of the Engine Committee.

FLAME-OUT CONDITIONS IN TURBOJET ENGINES were discussed by W. D. Rayle, head of the High Energy Fuels Section, Lewis Flight Propulsion Laboratory, at the January meeting of the Aircraft Gas Turbine, Ramjet and Rocket Engine Ignition Subcommittee. Areas covered in the talk were ingestion of rocket exhausts from missiles fired from the aircraft, blade stall due to over-acceleration, flame stability, compressor stall, and combustion efficiency as affected by (1) time of chemical reaction and (2) turbulent mixing, assuming negligible vaporization time.

SEAL PERFORMANCE PREDICTION TESTS are being established by a new Coordinating Research Council Steering Group on Seals. Emphasis is being placed on the effect fuels have on fuel systems, and fuel dispensing systems, power transmission fluids, engine lubricants, and gear oils.

RIDE AND VIBRATION INSTRUMENTATION PROBLEMS will be explored in the new Instrumentation Subcommittee of the SAE Riding Comfort Research Committee. V. D. Polhemus, General Motors Technical Center, has been appointed chairman.

MACHINABILITY RATINGS OF ALL FERROUS MATERIALS will be developed by two divisions of the Iron and Steel Technical Committee. The project will be handled jointly by Division 9, Automotive Castings, and Division 11, Machinability.

A NEW 'INSTRUMENTS FOR PREVENTIVE MAINTENANCE INSPECTIONS SUBCOMMITTEE' has been created by the Transportation and Maintenance Technical Committee. The group will develop reports for maintenance equipment. A. W. Neuman, Willett Co., has been appointed chairman.

J. C. WIDMAN, Ford Motor Co., has been appointed chairman of the Body Engineering Committee. He succeeds **E. A. ALLEN,** Schonitzer Engineering Co. **D. J. SCHRUM,** Studebaker-Packard Corp., is 1958 vice-chairman.

New Report on Hydraulic Control System Released

A TYPICAL hydraulic control circuit of an automatic transmission is presented in the new SAE Recommended Practice on Hydraulic Control Systems for Automatic Transmissions. The report is applicable to transmissions requiring control valves to change the gear ratio. The valves in turn actuate friction element servos.

Covers Essentials Only

The new report is representative of most control circuits in current use, and includes only the essentials. Covered are basic driver requirements, servo mechanisms, basic system requirements, automatic shift valve function, and the pressure-time relationship.

Developed by Controls Subcommittee

The recommended practice was developed by the Controls Subcommittee of the Transmission Committee. Subcommittee personnel include Chairman W. R. Rodger, Chrysler Corp.; H. W. Christenson, Allison Division, GMC; B. C. Erickson, Ford Motor Co.; W. B. Herndon, Detroit Transmission Division, GMC; R. W. Wayman, Warner Gear Division, Borg-Warner Corp.

6 New ARPs, 2 Revised Reports Now Available

SIX new Aeronautical Recommended Practices and two other revised reports are now available from SAE in loose-leaf form or separately.

ARP 24A—Determination of Hydraulic Pressure Drop
AS 341D—Nomenclature for Aircraft Engine Parts
ARP 427—Pressure Ratio Instruments
ARP 462—Shafts for Ball Bearing Retaining Spanner Nuts and Key Washers
ARP 464—Mount-Thermocouple
ARP 465—Flange-Thermocouple Mounting 1.500 Centers
ARP 466—Flange-Thermocouple Mounting 1.875 Centers
ARP 568—Uniform Dash Numbering System for O-Rings

Three New AMSs Released by Society

THREE new Aeronautical Material Specifications were released by the Society on March 1. They are:

AMS 4926 — Titanium Alloy, 5A1-2.5Sn, Annealed — 110,000 psi Yield
AMS 4951 — Titanium Wire
AMS 4953 — Titanium Alloy Wire, 5A1-2.5Sn

Briefs of SAE PAPERS

Continued from page 6

combination featuring expendable spark plugs was developed by Ford Motor; studies on effect of indicator-to-adapter clearance space, effect of indicator passage dimensions, etc; detection of abnormal combustion; auto and surface ignition; correlation of phenomena with engine noise.

Investigations of Dynamic Loadings of Automotive Hypoid Gears, D. L. POWELL, H. R. BARTON. Paper No. 254 presented Nov. 1957, 22 p. Study undertaken by Armour Research Foundation and sponsored by Ordnance Corp, concerned with unknown parameters of hypoid gear lubrication, in particular, magnitude of tooth loading at normal and severe operating conditions; methods used in study of transients produced by shock loading of drive systems, employing passenger cars and Army M-37 and M-211 trucks.

GROUND VEHICLES

Performance and Operational Characteristics of Automotive Fuel Injection, W. C. SUTTLE, F. C. MOCK. Paper No. S29 presented Sept. 1957 (Chicago Sec) 13 p. Discussion confined to spark ignition engines; principles and advantages of fuel injection; applicability to sport cars, motor truck and bus engines and light executive aircraft; requirements for fuel feed; selection of injection types; problems dealing with ram manifolding; effect of intake air temperature on torque; acceleration and deceleration; vapor handling.

Fumigation Kills Smoke, Improves Diesel Performance, M. ALPERSTEIN, W. B. SWIM, P. H. SCHWEITZER. Paper No. 248 presented Nov. 1957, 29 p. Method, developed by Dept of Eng Research of University of Pennsylvania, which consists of introducing part of fuel in form of fine mist into intake manifold while rest is introduced in conventional manner; fumigation helps combustion by better air utilization due to premixing and more complete combustion due to chemical effect of fumigation; test results; features of Norgren Micro-Fog mist generator; applications.

What MGM Brake Is and How It Functions, J. MYERS. Paper No. S44 presented Dec. 1957 (Northwest Sec) 6 p. System consists of individual wheel protection; it entails mechanical and automatic application of brakes on each wheel when air fails or falls below predetermined psi; degree of protection depends upon number of units installed; its application as parking and emergency brake; results of

Briefs of SAE PAPERS

tests; details of model 410-80 for highway vehicles, and 511 and 611 for heavy duty off highway units.

Principles of Earthmoving with Scraper Equipment, D. K. HEIPLE. Paper No. S33 presented Nov. 1957 (New England Sec) 11 p. Factors which result in overall job efficiency of scraper equipment in field; procedures for handling maximum loads by means of pusher loading, downhill loading, straddle loading, chain or shuttle loading and loading to maintain slope; rubber-tired unit and its various operations; tandem operation and double-bucket scraper; rubber-tired prime mover.

Brake Balance Between Axles, Original Design and Field Corrections, H. T. SEALE. Paper No. S2 presented Oct. 1957 (Northwest Sec) 5 p. Attempt to find simple method for use on tractors and trailers in field to bring axles of combination into workable balance to minimize differences in deceleration values between axles; variables affecting unbalance; use of duplex examples of unbalanced braking; gage for measurements; how suitable maintenance costs and stopping distances depend on suitable brake balance between axles.

Compressed Air Spring, C. O. SLEMMONS. Paper No. S31 presented Dec. 1957 (Metropolitan Sec) 9 p. Development of air spring by General Tire & Rubber Co to achieve smallest package possible for given pressure; approach taken in achieving reduction in size of basic spring, eliminating exterior compression chamber and achieving substantial reduction in weight; applicability to truck and trailer tandems and other vehicles.

Air Suspension on Highway Tractors, J. G. LOCKLIN. Paper No. S43 presented Nov. 1957 (Cincinnati Sec) 8 p. Application to tractors of some advantages gained in change from leaf spring to air spring suspension on motor coaches; these have included increased riding comfort; constant platform height, decreased maintenance, reduction of fatigue loads, and lower body height; General Motors Corp application of air suspension to highway tractors; details of installation.

Riding on Air. Paper No. S36 presented Nov. 1957 (Detroit Sec) 30 p. Paper consists of following articles each dealing with design details of system and components, etc: 1958 Pontiac Air Suspension, H. ALDIKACTI, 13 p; 1958 Cadillac Air Suspension, E. W. ANDERSON, 7 p; 1958 Edsel Air Suspension, R. D. HARRISON, 10 p.

Continued on page 113

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Continued from page 111

Looking Into Crystal Ball on Future Automotive Power Plants, C. G. A. ROSEN. Paper No. S41 presented Oct. 1957 (Texas Gulf Coast Sec) 12 p. Discussion confined to engines utilizing petroleum products for fuel and lubricants; economic and design considerations which confront design engineer; analysis of fuel situation; fuel injection systems and all aluminum engine; advances in diesel combustion methods; MAN Whisper engine; MWM balanced pressure combustion system; gas turbine and free piston engine; lubrication research.

PRODUCTION

Vacuum Metallizing of Cadmium on High Heat Treated Alloy Steels, V. DRESS. Paper No. 217 presented Oct. 1957, 16 p. Results of investigation of vapor phase deposition of heavy metallic films show practicability of method as possible substitute for electrolytic process; equipment and processing used; it is concluded that coatings are applicable to high heat treated low alloy steel without embrittlement, meet requirements of Specification QQ-P-416, and are compatible with processes applied in finish systems used for aircraft parts.

Techniques of Cadmium Electroplating Reduce Hydrogen Embrittlement, W. F. HAMILTON, M. LEVINE, R. C. MAUER. Paper No. 218 presented Sept.–Oct. 1957, 13 p. Development of bending apparatus and test method for investigations at Lockheed Laboratory; studies undertaken to establish processing conditions minimizing possibility of embrittlement; results of vendor tests in cadmium cyanide plating setups and laboratory tests; tests run in fluoborate, organic electrolyte, and modified cadmium cyanide baths.

Engineering Tolerances Applied to Industry, E. L. BYRKETT. Paper No. S42 presented Dec. 1957 (Southern New England Sec) 6 p. Five categories of tolerancing problems and five groups affected by such problems, including work shop, gage manufacturer, gage inspection facilities, and industrial and national standards laboratories; value of gage blocks; other measuring standards; efforts to extend tolerancing to seventh decimal place; future prospect of measuring tolerances down to 10^{-13} in. by electron waves.

These digests are provided by Engineering Index, which abstracts and classifies material from SAE and 1200 other technical magazines, society transactions, government bulletins, research reports, and the like, throughout the world.

Glass Ranks as True Engineering Material

Based on talk by

W. W. SHAVER
Corning Glass Works

(Presented before SAE Detroit Section)

GLASS can be made with a density lighter than cork; almost as heavy as iron; in hardness range from amethyst to turquoise; in controlled radiation transmission in the infrared, visible, ultraviolet, X-ray, and gamma-ray regions of the spectrum; in mechanical strength stronger than cast iron; in resistance to heat shock from beyond yellow heat to ice water.

Glass foam can be made in a range of densities down to a value of two-thirds the density of cork with a high thermal insulating value and impervious to moisture. Glass fibers provide the base for a new industry with their sizes ranging down to values best measured with an electron microscope.

A new field of materials has been discovered recently in which the composition is melted and worked as glass, then a subsequent heat-treating produces a conversion to a fine crystalline material. These materials are known as glass-ceramics. They can be made in a wide range of compositions and properties. Work is now in progress to bring glass-ceramics to commercial production.

Truck Must Fit Job For Operating Profit

Based on talk by

GEORGE U. BRUMBAUGH
Peterbilt Motors Co.

(Presented before SAE Northern California Section)

THERE is no universal solution to the problem of profitable truck operation. Disparity in operating conditions, weight and bulk of load, and length of haul require equipment to be selected in the light of the many influencing factors.

Weight is one of the most important factors. Minimum tare weight of equipment permits maximum payload within legal restrictions. Materials, design, and construction of all components must contribute to overall lightness.

Cubic capacity has become increasingly important in recent years. Except for some specialized hauling, the limitations of available loading volume are often reached before utilizing maximum allowable gross weights. To meet these conditions there are combinations such as doubles with a load-

ing length up to 50 ft, trucks and trailers which attain a maximum of 52 ft, and the dromedary train of 53.5 ft, all within the western legal limit of 60 ft of overall length. These trains require COE trucks to reduce driver space.

Since load width and height are fixed at 8 and 13.5 ft, respectively, the only other way to increase cubic capacity is to lower the frame and fifth-wheel heights. This accounts in part for the recent trend to smaller tires.

Driver costs, to a large degree, are proportional to time spent on the road. Running hours can be influenced by powerplants adequate to save time on upgrades, brakes which allow maximum safe downhill speed, and properly spaced transmission combinations and suitable gear ratios to contribute maximum average speed through full utilization of available horsepower.

Time spent in terminals and available for normal servicing affects equipment utilization. Doubles, or semi-trailer trains do not tie up power units for loading, while doubles also provide a more flexible combination for pickup and delivery.

Selection of powerplant size and type not only influences road speed, but also is dependent on economy of operation, cost of the particular fuel, and effect of its weight (including necessary containers) on the vehicle tare weight.

Hours lost in the shop, because of excessive maintenance or difficulty in making repairs, greatly affects revenue. Lack of reliability on the road is expensive and may result in loss of perishable freight.

The driver needs a comfortable cab. He can perform his job more efficiently and safely if provisions are made for good vision, ease of operation, convenience in grouping of controls and instruments, adequate ventilation and heating, and good seating.

Initial cost is important, but not as important as many of the factors mentioned because most trucks are used over a long period of years. Relatively cheap, underpowered, and inadequate units will get the freight through eventually, but the overall cost may far outweigh the saving in initial cost.

Numerical Control Gives Multipurpose Flexibility

Based on secretary's report by

A. F. ESKELIN

Northrop Aircraft, Inc.

NUMERICAL control is a machine operation of a different type than found in mass production factories. With numerically controlled machines there is multipurpose flexibility in one piece of automatic machinery. Within the size capacity of any machine, an enormous variety and shape of parts can be made.

Numerically controlled milling machines are designed and intended to produce machined parts automatically with a minimum of human intervention. However, for the use intended, other than automatic operation is provided. This manual operation provides intermittent or jog operation and continuous or traverse operation. With the manual mode, simple machining can be achieved, if desired.

While the machine is on automatic, the operator needs only to observe the machine's performance. Human errors are minimized since procedure is simpler and far fewer setups are made. The results are parts having increased accuracy and better quality. Metal removal takes place from 30% to 75% of the time instead of less than 10% of the time, as is the case with a majority of machines in present use. Lead time to first production is much shorter.

Manual operations performed by the operator are reduced greatly, and those he does perform can and should be simpler and quicker. Setup time can be reduced greatly over template tracing methods. Operator decision de-

New Kenworth 803-B rear dump truck with Fuller 4-speed Transmission hauls 64-ton payloads.

KENWORTH'S *new mountain movers feature* FULLER *Transmissions*

Probably the largest rear-dump semi being built today, Kenworth's 42′ 2½″ rock and ore mover is equipped with a Fuller heavy duty 4-speed Transmission.

The 228,000 lb. gvw Kenworth 803-B is designed to haul top payloads profitably over varied terrain. It is powered by a single 12-cylinder diesel engine, offered in either the 400 or 600 hp range. In the 400 hp version, illustrated, a Fuller 4-speed 4-MS-1440 Transmission with CO-11,500 Twin Disc Torque Converter delivers power efficiently and effectively from the powerful Cummins NHV series engine. These heavy-duty Fuller Transmissions provide the right gear ratios to apply the power profitably.

More than 100 different transmission models are available for rubber-tired equipment from 100 to 600 hp, 330 to 1550 cubic inch engines. Check with your truck manufacturer or write Fuller for the right transmission for *your* job.

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lays are minimized. Many former manual operations can be eliminated, such as layout of the workpiece, gaging, and manual indexing to set a block for each cut. The cutter path will be automatic and for all practical purposes not under the operator's control.

Others serving on the panel which developed the information in this article were: **B. Galennie**, Northrop Aircraft, Inc.; **G. E. Kinney**, Hughes Tool Co.; **E. K. Carlberg**, Boeing Airplane Co.; **W. P. Robertson**, Northrop Aircraft, Inc.; **O. A. Foss**, North American Aviation, Inc.; **L. H. Ferrish**, Lockheed Aircraft Corp.; **M. C. Copold**, General Dynamics Corp.; and **W. J. Kinney**, Douglas Aircraft Co., Inc.

To Order SP-321 . . .
on which this article is based, see p. 5.

Trailer Makers Cutting Down Weights

Based on talk by

ROY K. WALTHER

Trailmobile, Inc.

(Presented before SAE Northern California Section)

PLASTICS are being used for skylights and inside linings of trailers to reduce weight. Other uses are being explored, but the stumbling block is still in the fastening. Plastic doors for both insulated and noninsulated trailers are being experimented with, but the need for variation in height has made production of them uneconomical.

Aluminum in the body construction is responsible for major weight savings, great strides having been made with monocoque or stressed skin design. Problems of flexibility in production have restricted use of aluminum for flatbed trailers.

In the past year we have been able to reduce tandem suspension weights by 50 lb and single suspension weights by 25 lb through redesign of radius rods, spring hangers, spring seats, and complete electronic test. New model trailers having specifications identical with the old have been offered within the past year with weight savings as follows: flatbeds, 24 ft - 590 lb, 35 ft - 550 lb, 40 ft - 600 lb, and a 24-ft van - 474 lb. Corresponding cost savings have accrued from the lower material cost gained in weight reduction and from better assembly methods to lower labor hours per unit.

Sometimes a more satisfactory unit can be had by increasing the cube and the weight of the trailer. This is particularly true on the East Coast, with its 12.5-ft height limit. With a new design of a fifth-wheel structure, 2¾ in. deep, to replace the previous 4- and 7-in. structures, the 6-in. drop units have been eliminated. This type of low level, upper fifth-wheel construction provides the same cube in a straight frame unit formerly possible on a 6-in. drop unit in the 35-ft length.

The bronze bushing, formerly used at the one point of lubrication on the tandem assembly, has been replaced by a phenolic resin bushing which will give twice the life under proper care and equal the life of the bronze bushing without care.

To lower production costs we have installed a roof drilling and screwing fixture which automatically drills and screws roof sheets to both sides of the trailer on 1-in. centerlines up to 40 ft long. One operator can put in about 1000 screws in 15 min.

New design flatbeds coupled with removable hoppers make possible easy conversion of a flatbed trailer into a hopper and back again to the flatbed for seasonal runs of various commodities.

Flatbed design used to require all-steel construction at all times. New designs permit a choice of aluminum extrusion or structural steel bolsters. Our body design permits a choice of aluminum or steel for post, quarter panel, lower rail, and bolsters according to the operator's requirements.

Continued on following page

Mechanical Brakes Stop Trucks in Trouble

Based on paper by

J. MYERS
M. G. M. Brakes Co.

(Presented before SAE Northwest Section)

EMERGENCY braking is applied mechanically in the MGM wheel protection system when the regular air service brakes fail. Loss of air pressure unleashes a compressed spring which pushes on the slack adjuster arm, applying the service brakes. The brakes are not released until air pressure is built up. Also, the emergency braking is effective indefinitely since it is applied by a spring. This makes the system useful as a parking brake . . . the driver bleeds the air from the MGM system by opening a separate valve.

The spring is compressed in a cylinder by a piston. A 76-psi air brake line pressure is enough to bottom the spring in the highway vehicle model. Tests show 70% of maximum service braking ability when the emergency system is used alone. Since springs apply a resilient braking force, there is little tendency for the brakes to grab due to high or hard spots on the brake linings.

To Order Paper No. S44 . . . on which this article is based, see p. 5.

Effect of H-C Type On Fuel Road Ratings

Excerpts from paper by

W. A. P. MEYER
and
R. G. GOLDTHWAIT
Gulf Research & Development Co.

SIX major conclusions can be drawn from recent Gulf studies of 13 blended fuels to determine the effects of hydrocarbon type and distribution in the boiling range on road performance at what is now the approximate Research octane level of premium gasolines. They are:

1. Fuels of approximately the same Research octane number possessed marked differences in road rating characteristics in any given test car. The road rating of each fuel also varied from car to car. The relative road rating characteristics, however, were generally similar in each test car.

2. Road ratings of fuels of a given Research octane number varied with sensitivity and hydrocarbon type when tested at the maximum obtainable throttle opening. A decrease in sensi-

tivity resulted in an increase in road rating. When the sensitivity was due to aromatics the road ratings were higher than when it was due to olefins. Both effects were more pronounced at high speeds than at low speeds.

3. Fuel sensitivity and aromatic content were also important factors in road performance under part-throttle conditions. The detrimental effect of sensitivity increased with an increase in intake manifold vacuum. Also, at constant sensitivity, the beneficial effect of aromatics increased with an increase in intake manifold vacuum.

4. Distribution of olefins in the boiling range had no apparent effect on road ratings of fuels which also contained paraffins but negligible amounts of aromatics and had normal volatility and similar Research ratings and sensitivities.

5. In general, distribution of aromatics in the boiling range had little, if any, effect on road rating of fuels which also contained paraffins but negligible amounts of olefins and had normal volatility and similar Research ratings, sensitivities, and aromatic contents.

6. There were indications that the combination of light aromatics and heavy olefins had poorer road performance characteristics than those of the combination of light olefins and heavy aromatics.

To Order Paper No. 258 . . .
on which this article is based, see p. 5.

Power Take-off And Drives Discussed

Based on secretary's report by

ROBERT L. MORSE

Truck Engineering Corp.

(of panel discussion on Truck Power Take-off Drive Applications)

VIEWS exchanged at this meeting reflected dissatisfaction among users with the attention given by vehicle designers to power take-off and drive installations; also with the variations of the provisions for installing power take-offs.

Armour Study Gives New Hypoid Lube Data

Based on paper by

D. L. POWELL

and

H. R. BARTON

Armour Research Foundation

NEW data on transients produced by shock loading of motor vehicle drive systems have been produced in a recent study of the magnitude of hypoid gear tooth loading at normal and severe operating conditions. This magnitude, still one of the unknown parameters of hypoid gear lubrication, was a chief objective in the beginning of investigations of dynamic loadings of hypoid gears undertaken by Armour Research Foundation for the Army Ordnance Corps.

Chief conclusions from the first progress report resulting from these studies are:

1. With heavily loaded trucks the climbing of steep grades can increase the ring gear torque as much as 13–24 times that of level road load under steady speed.

2. The addition of trailed loads causes large increases in gear torques. In one truck studied, gear loadings appeared to increase exponentially with an increase in the trailer gross load.

3. The highest gear loads produced under normal operating conditions in both automobiles and trucks occur as a result of gear shifting.

4. Engine misfiring resulting from spark-plug fouling causes repetitive

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- **Lower pedal load!**
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Here's the first in a new series of Lipe direct pressure clutches to supplement the already-famous DP Line! With the introduction of the new 12" DPB single and two plate, Lipe direct pressure clutches are available for all applications involving gross vehicle weights of 19,000 lbs. and up. Additional DPB models in 13" through 15" single and two plate sizes will be available soon.

The new Lipe 12" DPB clutch is interchangeable with many other models and is easily adapted to any present vehicle requirements. Improved design, a simpler, sturdier internal lever system, and Lipe's precision manufacturing and testing assure you extra clutch mileage in your vehicles.

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gear loadings equal to the 60-mph drive side shock in the CRC L-19 test.

5. Changes in the rate of throttle opening result in large differences in the drive side shock loadings of the gears. The substitution of electric solenoid throttle controls for hydraulic controls in the CRC L-19 test nearly doubled the drive side shock torque.

6. The rate of throttle closing appears to have little measurable effect on the coast side gear shock loads. These loads appear to be more directly a function of the inertia of the vehicle and drive system and the elastic properties of the drive train.

7. Shocks such as those imposed in the VV-L-761 shock test or in gear shifting of heavily loaded trucks on steep grades produce severe lubrication requirements by imposing large stepwise changes of loading on a contact point in one revolution of the pinion.

To Order Paper No. 254 . . .
on which this article is based, see p. 5

Time a Factor in Knock Correlations

Based on paper by

J. H. MACPHERSON, J. A. BERT, AND K. L. KIPP

California Research Corp.

THE time factor must be considered to improve correlations between knock and various engine variables, such as end-gas pressure and temperature. In our opinion, a method for predicting knock must depend on development of a means for calculating accurate end-gas temperatures and densities with proper allowance for a time function.

Such an allowance has not been made in most previous methods.

Without such an allowance for time misleading correlations can result from currently used methods. The importance of time can best be illustrated by the Texaco combustion process. Residence time of the unburned gas in this cycle is essentially zero, and the engine cannot be made to knock.

Bearing out these conclusions are results of a recent California Research Corp. test program to determine the effect of engine variables on the knock-limited performance of one fuel and the relationship between these data and calculated end-gas conditions. The tests were conducted in a Merz 17.6 cu in. displacement engine. The fuel was isooctane.

Five chief conclusions to be drawn from these tests are:

Conclusions

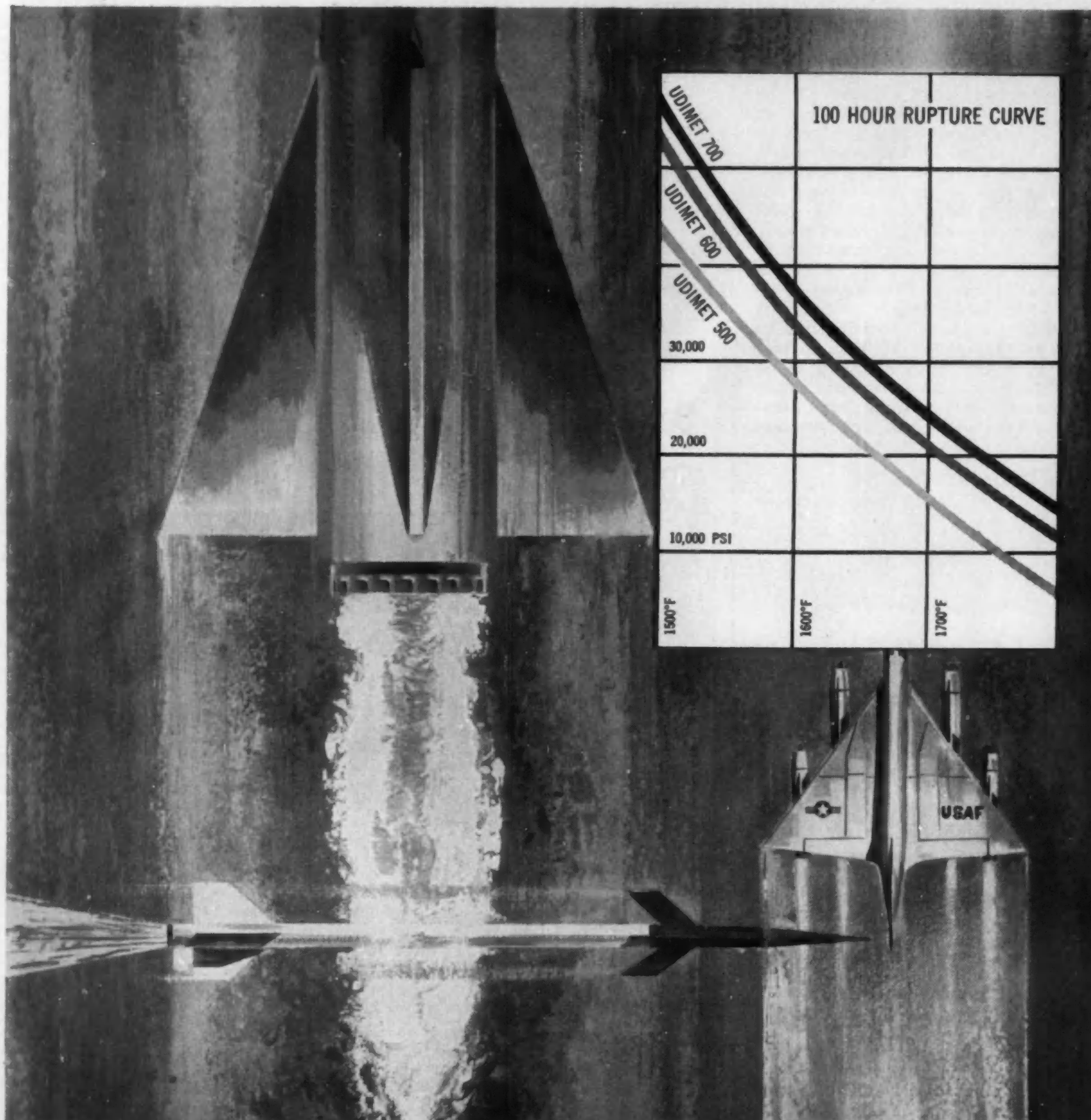
1. The temperature, density history of the fuel-air mixture must be known to predict the occurrence of knock. If time is neglected as a variable, erroneous fuel-engine knock correlations will result.

2. Fuel knock correlations can be developed if true values or values proportional to the true values of temperature and density at conditions of knock are known.

3. Calculated end-gas temperatures and densities or calculated peak compression temperatures and densities do not give values equal to or proportional to the true values of density and temperature at time of knock, except under limited operating conditions. This is because both methods assume peak conditions to occur at top dead center for all engine conditions, and neither method considers the effect of time.

4. End-gas temperatures and densities calculated by the peak pressure method give a better representation of the temperature and density at peak pressure than those calculated solely from inlet conditions. Pressure-time data are required to apply this method of calculation.

5. A great deal of additional pressure-time data will have to be obtained before a basic correlation can be developed relating the knocking charac-



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teristics of all fuels, to all engines, and all operating conditions.

To Order Paper No. 3A . . . on which this article is based, see p. 5.

Road Developments Affect Transmissions

Based on talk by

DONALD W. BEHRENS

Fuller Mfg. Co.

(Presented before SAE Northern California Section)

THE on-highway, long-haul, truck operator can expect higher average speed and shorter trip time if the projected highway program is carried through successfully. In other words, more of the trip home will be spent in a shorter range of available gears and drivers will shift less often and suffer less fatigue.

This should lessen the demand for more complicated and expensive automatic transmissions and enhance the value of an easily shifted conventional transmission with evenly spaced ratios to permit taking full advantage of highway conditions.

The exact opposite holds true for the short-haul, delivery-type operator. Ever denser traffic means more shifting, less work done in an 8-hour day, and greater fatigue. Under these conditions, the higher initial cost and maintenance expense of complicated automatic transmissions may be justified. Many manufacturers and fleet operators are studying this problem.

Computers Solve VTOL Hovering Problems

Based on paper by

GEORGE W. SMITH

Ryan Aeronautical Co.

COMPUTERS helped solve the hovering problem of a VTOL aircraft in recent tests on the Ryan X-13. Pilots tend to overcorrect because the jet engine doesn't respond immediately to throttle controls. This gives the aircraft a bouncy motion.

A one-degree-of-freedom weight-thrust system is fed into a Geda analog computer. The computer controls a servo throttle system with 5% of full thrust authority. The vertical accelerations of the airplane are detected by an accelerometer, relayed by the

computer to the servo control, which in turn adjusts the throttle setting.

The pilot can override the system due to a rate-of-change detector on the manual throttle. This temporarily defeats the servo control.

An engine dead time of 0.1 sec was found as a result of establishing computer functions based on engine test data.

To Order Paper No. 233 . . . on which this article is based, see p. 5.

Automatic Transmission Seals Undergo Changes

Based on paper by

E. S. BOWER

and

B. C. VANDERMAR

Western Felt Works

THE flange or lip type seal, long popular for use in automatic transmissions as clutch and servo piston seals, has undergone considerable configuration changes since its early use.

The expander springs were dropped when it was discovered that the sealing lip interference was sufficient to hold incipient hydraulic pressure providing the resistance of the material to deflection set was good.

A recess was added to avoid a condition of rubber in compression and to assure desirable deflection action.

Later, the length of the lip was reduced, primarily a space-saving factor, while simultaneously it was decided to increase the lip thickness to provide resistance to hardening and cracking as thin sections exposed to heat and oil will deteriorate rapidly.

One manufacturer added a flat to the back of the lip which, under certain conditions, reduced friction. And, the base size was reduced to a more reasonable size from a material standpoint.

Thus engineers have arrived at an efficient practical design which, when manufactured of the proper material and tailored to fit the unit, will give excellent performance and durability.

Since the early days of the automotive hydrokinetic transmission the lip type seal has been a natural choice for many reasons.

The transmission designer had to have a seal that would allow an easy assembly of the piston with its seal into the bore. The flexible lip does this well by merely deflecting into position.

This same deflection sealing characteristic of the lip seal provides a near-optimum friction condition. That is, very little effort is required to deflect the lip and only a small amount of this resolves into resistance to move the piston.

The hydraulic pressure required to

move a piston into apply position also acts against the lip to effect a seal. At low pressures, the lip exerts relatively little circumferential force against the bore and the piston moves freely. At higher pressures, the lip is engaged with more force and does an effective job of sealing the higher pressures. There is a convenient ratio of seal friction to the sealed pressure which works in favor of hydraulic efficiency. Further, the friction is initially in a low range and continues low throughout the life of the unit.

With the use of the lip seal, there is no change in shift pattern because of wear. In addition, there is no loose rubber or mental particles to clog filter screens or cause malfunction in close-tolerance valve bodies and other small transmission control passages. Wear is negligible because the deflection action of the lip in the assembly is such that, while oil is effectively prevented from passing, the peripheral force is inherently below that critical point which would excessively stress rubber in tension, causing wear.

Where transmission calibration is important, the lip seal compensates for tolerance stack-up of piston, bore, and grooves. The lip deflects to a greater degree as stack-up tolerances combine, while the seal friction, or more important, the force to move the piston remains uniform. Likewise, bore out-of-round conditions are compensated for by the lip seal as the lip will easily follow the anomalies of the bore contour and, in addition tolerate considerable misalignment. Similarly, thermal changes of the piston and bore are easily accommodated by the flexible lip.

The lip type seal also offers cost savings. Recent tests indicate that bore-finish tolerances, which must be held at 50 microin. with most compression type seals and at 20 microin. with metal type seals, can be opened up to 100 microin. or better with lip seals. Likewise, bore-diameter tolerances currently held at ±0.001 in. may be relaxed to ±0.004 in. Groove diameters maintained at ±0.003 in. may now be pegged at ±0.004 in. And, groove widths specified at ±0.0005 in. or closer for metal seals and ±0.0025 in. for compression type rubber seals, may be relaxed to ±0.005 in. when the lip seal is used. The result—savings in tool, scrap, and manufacturing cost.

To Order Paper No. 1A . . .
on which this article is based, see p. 5.

Future Aircraft Likely to Feature New Developments

Based on secretary's report by

W. J. GUNN

Convair Division, General Dynamics Corp.

FOR future aircraft, the following developments are anticipated:

1. Aluminum will not be acceptable for high-performance designs.
2. There will be an increased use of steel and titanium.
3. Steel will be used for wing bending material.
4. Stainless steel with strength levels of 230,000 to 250,000 psi, and of extremely close tolerance, will be required.
5. Welding and brazing will be the primary joining methods.
6. All component tolerances will be closer.
7. More economical fabrication methods will be developed.

Others serving on the panel which developed the information in this article were: **A. P. Higgins**, Convair Division, General Dynamics Corp.; **A. C. Carlson**, Boeing Airplane Co.; **H. C. Emerson**, Rohr Aircraft Corp.; **G. W. Motherwell**, Wyman-Gordon Co.; **C. C. Pope**, Convair Division, General Dynamics Corp.; and **C. P. Rolla**, 4-D Engineering Corp.

To Order SP No. 321 . . .
on which this article is based, see p. 5.

$ Is Key to Truck Use Of Automatic Transmission

Based on talk by

W. S. COLEMAN

White Motor Co.

(Presented before SAE Mohawk-Hudson Section)

THE question is frequently asked, "What about the automatic transmission for heavy-duty trucks?" As long as truck drivers are willing to shift gears—a process that is being made easier each year—the progress of automatic transmissions will depend on economic considerations. Unlike passenger cars, heavy-duty trucks are seldom driven by their owners. Much of our truck design depends on its effect on the income it will produce. Economy is not readily sacrificed for driver comfort and convenience, as much as these items are desired.

With full knowledge of these conditions, much research and development have been conducted toward the goal of producing an automatic transmission that could be successfully marketed. At present only one automatic transmission—made by Allison Division of GM—has reached a fairly wide acceptance. Since it is available in several different torque capacities with the same exterior dimensions, it can be used behind engines over a range of 250–400 ft-lb of torque.

The complexity of an automatic transmission such as this one presents many problems. It is uneconomical to produce without elaborate and expensive tooling. This in turn requires high volume to keep costs within reason. There is the further problem of training the drivers and service personnel. Even if we assume that the design is good and that the production quality control is first rate, there is still the difficulty of diagnosing trouble and knowing what to do about it.

We're Not New In Missile Business

Based on talk by

REAR-ADM. JOHN T. HAYWARD, USN

(Presented before SAE Philadelphia Section)

ABOUT a year and a half ago, there became apparent a sudden national awareness of ballistic missiles. It was announced that the three services were all embarking on high-priority projects for the development of an intermediate-range ballistic missile—intermediate range being defined as about 1500 miles. There was much conjecture in the press as to whether the Russians were ahead of us in this field and there was a general air of urgency based on the apparent misapprehension that this country had only just awakened to the terrific possibilities and implications of this weapon.

I have been asked by people outside the missile business why we hadn't got going on this before. The simple answer is that we had. For years all the services have had programs of high priority for the development of essential components for ballistic missiles such as gyros, accelerometers, and high-thrust rocket engines, not to mention basic research in many areas. It seemed rather pointless in those days to spend large sums of money just to prove you could lob a king-size tin can 1500 miles without having a reasonable expectancy that it would come down approximately where you had told it to.

No, our apparent acceleration of interest is not because we have suddenly found out they are a good idea or that the Russians are working on them—it is just that we have arrived at the point where we feel sure we can do something significant about them.

Continued on following page

How Oil Quality Affects Operation of LPG Engines

Excerpts from talk by

WILLIAM FLOYD
Humble Oil & Refining Co.

(Presented before SAE Midcontinent Section)

LPG, SINCE it does not form varnish and does not contain lead, does not throw this load on the oil, but the burning of any fuel has some finite amount, however small, of soot, water, and products of partial combustion which get into the crankcase. The detergent in the oil has to hold the products in solution or suspension to keep them out of engines. If the detergent is good they can't be filtered out. The only way to get rid of them is to drain the oil Oil never wears out, theoretically, but it does become undesirable and no filter can reclaim a *good* detergent oil. The oil in effect acts as its own filter. It picks up the gunk and it holds it. How much detergency do you want? Well, this seems to be simply a matter of economics.

A good mineral oil might operate the engine for X hours before an overhaul becomes necessary. Under the same conditions a MIL level oil might make 1.5–2.0 X hours before an overhaul is necessary. Stepping the oil up to Supplement I might raise the value to 4X. In severe cases, it might take Series III oils to get 4X, but oil is a lot cheaper than steel. Thus, with oil of the right base stock and the right detergency level, the pistons, the rings, and the cylinders should be the last thing that will ever cause trouble. Your engine will operate for:

1. The *maximum length of time* without overhaul.
2. The maximum utilization of the fuel because of good rings.
3. The minimum of friction because of *no varnish* or *thickening* of the oil.
4. The engine will be kept at the proper operating temperature.

Two Ways Available To Stop Aircraft Skids

Based on paper by

G. H. COLLIER
Wheel & Brake Division, Goodyear Aircraft Corp.

PRESENT-day airplanes need skid control specifically designed for the mission of the airplane. This control prevents blowouts and decreases stopping distance. Skid Warning is an effective method where low cost, safety, and good stopping distances are needed. Automatic Anti-Skid is used

in those cases where faster control action is required.

Skid Warning is a pilot controlled method. The sole of the pilot's shoe is rapped sharply when a skid starts. This signal warns him to decrease brake pressure. The signal stops as soon as the threatened skid is past.

Automatic Anti-Skid detects the impending skid and operates a hydraulic valve which relieves brake pressure. The valve reapplies pressure after recovery from the threatened skid.

Both systems use change in wheel speed to detect a skid. A d-c motor is mounted in the wheel. Sharp changes in motor output signal the beginning of locked wheels.

The Skid Warning system has been dynamometer tested, installed on transport airplanes, and is being tested in a fighter. Pilots approve because their control of the airplane is the same, only specific knowledge of the wheel operation has been added. Pan American Grace Airways demonstrated that pilots can react in time to prevent flatting of tires under adverse conditions. Records from Panagra show a 14% average improvement in stopping distance.

Military transport planes used Automatic Anti-Skid for several years. No unsatisfactory reports have been made. In one case, strut oscillations caused by skidding were eliminated by Anti-Skid. Experience had shown that the landing gear could fail if brakes of skidding wheels were not released quickly.

To Order Paper No. 8B . . . on which this article is based, see p. 5.

Manned Satellites Present 2 Main Problems

Based on talk by

JOHN L. SLOOP

NACA Lewis Flight Propulsion Laboratory

(Presented before SAE Metropolitan Section)

PROBLEMS facing those concerned with the development of manned satellites are:

1. To get a reliable, reasonably sized rocket booster to accelerate a large payload to velocities on the order of 25,000 fps in the desired direction.

2. To design the man-carrying vehicle so it can withstand the aerodynamic heating problem on re-entry into the atmosphere.

To accelerate a payload to a high velocity requires a low ratio of empty weight to propellant weight and a high specific impulse (thrust/flow rate of propellants). There is a great incentive for the designer to eliminate all unnecessary structural weight and residual propellants left after the rocket ceases firing. There is, of course, a limit to how low the empty weight can go, as it includes the payload. There is equal incentive in increasing specific impulse which is a function of the propellant combination used and the pressure ratio of the gases in expanding through the nozzle.

High-energy propellants offer almost twice the specific impulse as propellants in present use. These high-energy propellants include fluorine and ozone as oxidants and hydrogen, hydrazine, and ammonia as fuels. Unfortunately, the properties that make these chemicals so good for propulsion make them very difficult to handle. Ozone and fluorine are toxic, corrosive, and are liquified gases. In addition ozone is highly unstable. Hydrogen has a very low density and is difficult to liquefy and keep as a liquid.

Research on handling, pumping, cooling, and performance problems of high-energy propellants is underway at the NACA Lewis Flight Propulsion Laboratory (see accompanying photograph) and other laboratories to make the use of these high-yield propellants a reality.

VIEW OF NEW NACA research laboratory that will enable scientists to probe the secrets of high-energy propellants for space rockets. It is capable of operating 20,000-lb thrust versions of upper-stage space vehicles using such potent propellants as flourine with ammonia, hydrazine, and hydrogen. The facility is unique in its scale, its ability to silence the rocket's roar, and in its ability to absorb harmful exhaust gases.


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New Members Qualified

These applicants qualified for admission to the Society between February 10, 1958 and March 10, 1958. Grades of membership are: (M) Member; (A) Associate; (J) Junior.

Atlanta Section

Robert O. Dickinson, Jr. (M), Eugene L. Newman (A).

Baltimore Section

Walter M Iwanowski (M), D. F. Ryder (M).

British Columbia Section

Victor C. Nelson (A).

Buffalo Section

Warren F. Williams (M).

Canadian Section

Ian F. Flemming (A), Carl David Purdy (M).

Central Illinois Section

Donald R. Amborski (J), Donald Henry Connor (J), Richard J. Heintzman (J), James A. Memmer (M), Joseph Louis Oberle (M), Melvin Harvey Page (M), Robert E. Rohman (A), Jack A. Rupert (J), Bruce C. Tibbetts (J), Robert W. Young, Jr. (J), Byron D. Zehr (J).

Chicago Section

Harold Bennett (M), John W. Braze (M), Barry L. Danner (A), Walter H. Schrader (M).

Cincinnati Section

Frank J. Rodgers (M).

Cleveland Section

Sherman S. Cross (M), Matthew J. Fleming, Jr. (M), Robert Creston Hudson (M), Jack J. Kroecker (M), John A. Matz (J).

Colorado Group

Frank A. Salvatore (J).

Dayton Section

Milton E. Feldstein (M), William J. Steinbruner (J).

Detroit Section

Titus Andrisan (M), Ralph W. Behler (M), Richard John Boike (J), James S. Brierley (M), Charles W. Daberkoe (J), Myron D. Dickey (M), Frederick Rupert Glass (A), Donald Everett Goss (J), John E. Haines (J), Roger H. Harrison (M), Dexter R. Hart (J), Herbert E. Jacobson (A), H. Bernhard Kulose (M), William Robert McGregor (A), Richard E. McMillen (M), Kenneth George Peterson (J), Richard B. Pratt (M), Joseph J. Serritella (J), Walter L. Sherry (J), Paul L. Silbert (J), Herbert G. Taracks (M), Seymour

Continued on page 141

New Members Qualified

... Continued

E. Voorhees (M), Kenneth E. Welke (J), Kenneth H. Wern (M), Claude T. Williams (J).

Indiana Section

Wilbur W. Carlson (M), James Philip Carpenter (J), James J. Creamer (M), Lowell Gene Stohler (A).

Kansas City Section

Donald K. Edens (A).

Metropolitan Section

Norman Neiman (J).

Mid-Continent Section

C. A. Hubble (A).

Mid-Michigan Section

James Burns Bay (J), William C. Eaton (M), Joseph P. McGrail (M), Leonard L. Osgood (M), Marshall Hoyt Wright (M).

Milwaukee Section

Dobri Christoff (M), Richard Glasson (A), Robert Turner Johnson (J), Walter J. Langkau (A), Kenneth I. Olson (M), Robert J. Sroka (M), Willard O. Tschantz (M), William H. Wulff (J).

Montreal Section

R. M. Dunton (M), Barrie R. B. Hall (J), Norman Neath (A), Thomas Anthony Threapleton (A).

New England Section

Donald C. Alexander (M), John E. Kent (J), Francis J. Post (A), Richard W. Wilby (A).

Northern California Section

Thomas J. Dahm (J), Frank J. Davis (M), Delbert D. Ehrlich (J), Tom Sifton (M).

Northwest Section

Donald B. Menzies (J), Frederick Allan Raupp (J).

Philadelphia Section

Paul E. Hagstrom (J), J. Carl Moore (M).

St. Louis Section

Patrick Joseph DeLuca, Jr. (J).

San Diego Section

Willis John Christman (M).

South Texas Group

William P. Teich (M).

Southern California Section

Vincent N. Capasso, Jr. (J), Joseph Darrel Cypher (J), Harry Jaffe (A), Everard P. Larned (A), James J. Loggie (M), George E. Schaetzel (M), Sidney R. Shannon, Jr. (M), Willard D. Sparkman (J).

Southern New England Section

David J. Asquith (M), Robert O. Cooling (M), M. Allen Magid (J), James Lawrence O'Brien (J), Malcomb Edward Tumey (J), Clyde A. Walb, Jr. (M).

Spokane-Intermountain Section

Robert G. Anderson (A), George S. Headstrom (A), Robert Paul Schwartz (J).

Texas Section

W. S. Dixon (A), Norbert A. Kouyoumdjisky (A).

Texas Gulf Coast Section

Kenneth Brady (M), Fred N. Lamoureux (M), Alfred O. W. Wedel (M).

Twin City Section

James V. Brady (M).

Outside Section Territory

Richard H. Guscott (M), Wilford G. Kilpatrick (M).

Foreign

Roy Lenton Ashley (M), Australia; K. A. Mitter (M), India; A. V. Varughese (J), India.

Applications Received

The applications for memberships received between February 10, 1958 and March 10, 1958 are listed below.

British Columbia Section

Kenneth G. Clarke, Richard P. Shaw

Buffalo Section

George S. Nash

Canadian Section

M. E. Bailey, Charles Michael Bell, G. Richard di Dio, Desmond McIntosh Donaldson, G. Bruce Hood, Donald S. Horne, Hjormund Kummen, Jack Skead McAvoy, W. H. Schmalz, William Somners Wilkinson

Central Illinois Section

Winton A. Hancock

Cincinnati Section

Stanley C. Ademek, Odd Hagbard Alme, Raymond I. Birkholz, Warren G. Clark, Edward D. Duke, Joyce N. Foster, Kellog Huntington, Jr., G. Robert Jordan, William A. Lucht, James J. Nawrot, Frank Nemeth, Kendrick O. Renz, Robert P. Smith, Jr., Harry P. Wertheimer, Stanley Worthington

Chicago Section

Joe W. Savage, Jr., Bert E. Sells, Joseph F. Shemenski, J. Gray Stuart, Richard B. Williams

Cleveland Section

William S. Giles, John K. Hulbert, E. A. Kure, James E. Quinnell, Robert M. Raney, David Edward Rees, George R. Smolak, James C. Wallace

Colorado Group

Milford J. Bishop, David R. Kerr, Jr., George W. Lovering, Jr., John W. Post

Dayton Section

John J. Segreto, Fred Walther

Detroit Section

Dan H. Andrews, Henry C. Bujak, John P. Burley, Joseph M. Callahan, Joseph E. Couvreur, Joseph F. De Marco, Arnold H. Echola, S. T. Foresman, Robert Harry Harlow, Fredric H. Kaehler, Frank J. Kalvelage, Jr., Edward L. Kary, Kent B. Kelly, Robert R. Kerr, Verne T. Koppin, Charles Wm. Livingstone, Ralph K. Londal, W. L. Mosher, Jr., George J. Nebel, Irwin Joseph Reps, Charles I. Robins, Giacomo Mario Romeo, William Walter Ryba, Joseph Saia, Dr. Philip Weiss, Ralph J. Wieneke, G. Bruce Wilson

Indiana Section

Arthur W. Alexander, Kenneth Eugene Kritsch, Kent August Ziegler

Kansas City Section

C. L. Strahota

Metropolitan Section

Maximillian Karl Brand, Edward B. Capliski, George M. Lorca, Ernest R. Politz, Allan Wittman, Walter Young

Mid-Michigan Section

Carl G. Rummel, Richard B. Thomson, Andrew K. Watt

Milwaukee Section

Robert H. Bergquist, Robert L. Lewis, Elmer A. Rasmussen, Edgar A. Wellens

Montreal Section

Jean Gerard Arcand, Walter Edward Day, Jean F. DeCelles, Elmer James Greenway, Thomas George Oates, James Robert Proctor, Charles J. Tanner, Alan Lawrence Taylor, John Edward Taylor

New England Section

A. Robert Campbell, Arthur Napolitano, Ernest A. Sidney

Northern California Section

Paul Darneley Hobson, Robert P. Labrucherie, John Albert Thompson

Northwest Section

James Harold Routledge, John William Tripp

Oregon Section

Wesley M. Foughty, William J. Kimmell

Philadelphia Section

Robert L. Bour, Miles A. Bowman, David C. Hathaway, Richard E. Newman, Jr., Anthony R. Patterson, Charles J. Prizer, H. Frederick Strohl, James Edward Transue, Jr., John H. Zabel, Jr.

Pittsburgh Section

J. Russell Hanson, Richard Arthur Johnson, William H. Johnston, Richard D. Rogerson

St. Louis Section

Fred E. Boesch, R. W. Filkey, Jr., Robert B. Oetting

Salt Lake Group

John E. Medosch, Robert John Schramm

San Diego Section

Jeronimo Maestro

South Texas Group

Nelson T. Meckel

Southern California Section

Robert S. Baird, Hyman M. Kellner, Richard H. Khuen, Thomas H. Smith, R. W. Thompson

Southern New England Section

I. James Elmore, Irvin M. Frankman, Clifford R. Fales, Walter A. Schlegel, David Bernard Scott, Paul A. Yale

Spokane-Intermountain Section

Ray Saling

Syracuse Section

William Gillespie, Nelson H. Mageoch

Texas Section

Francisco X. Coronado, D. M. Grigsby, John B. Meriwether, Gerald E. Stewart

Twin City Section

Clare B. Palin, John Nicholas Senzig

Virginia Section

Carroll Spencer Winn

Washington Section

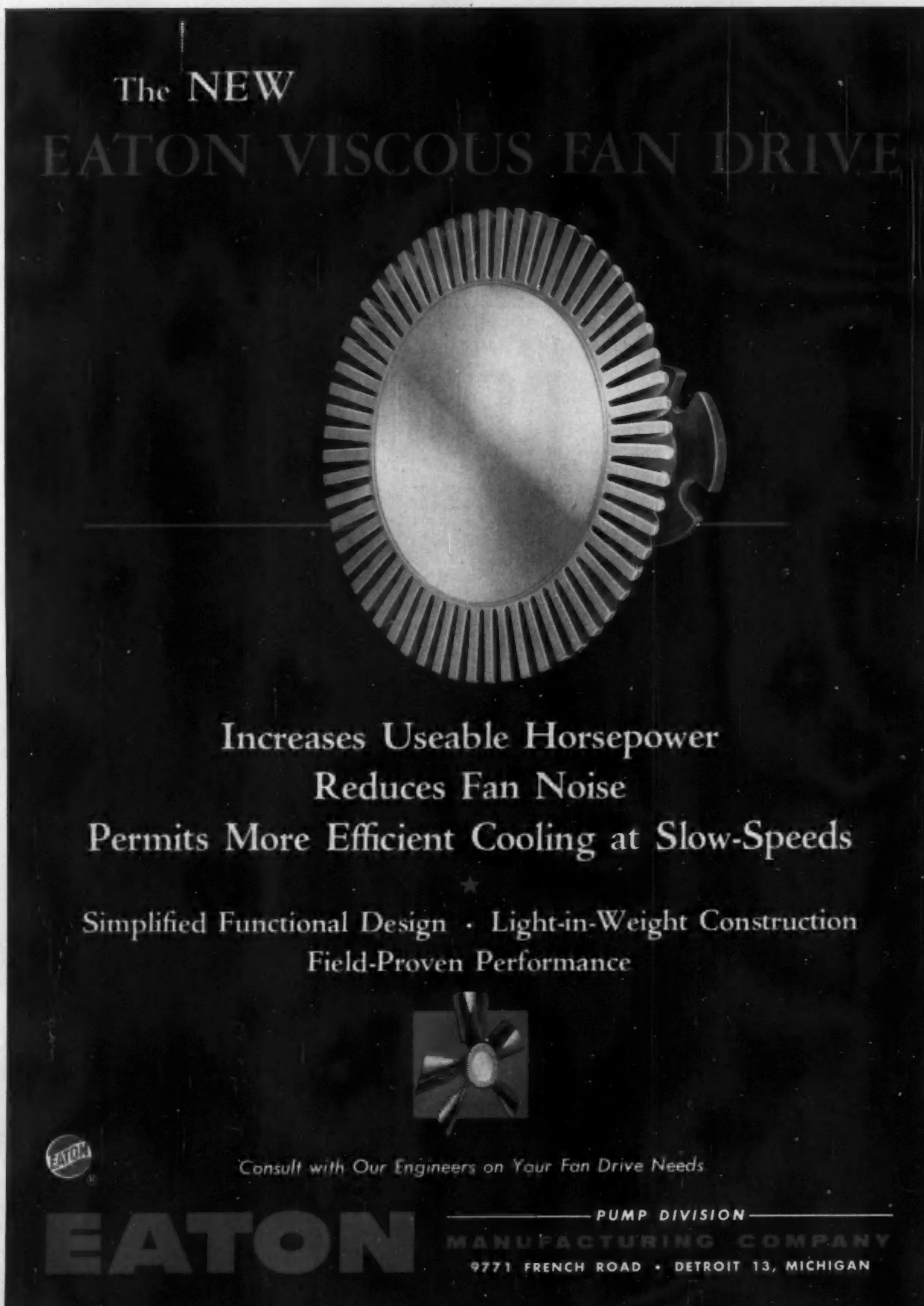
Anthony Thompson

Outside of Section Territory

Harold Buckholdt, Harvey J. Crane, Jr., Carl F. Gerken, Winford B. Hickman, Frank A. Johnston, Ross J. Seymour

Foreign

Major V. P. Gulati, India; Marie Claire Cibie Merenda, France; Norbert Nissan Reis, Israel; Walter Edward Withers, South Africa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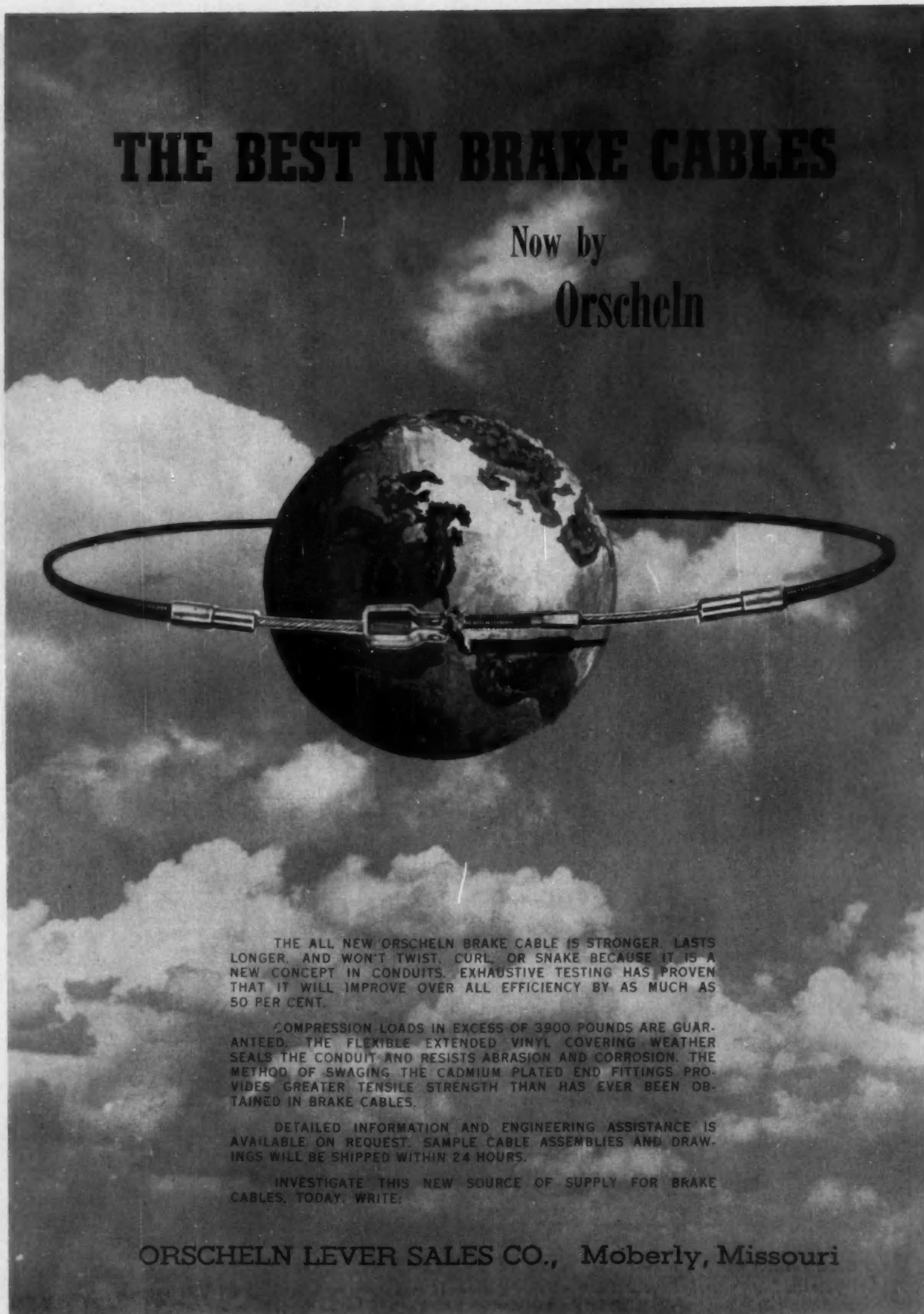

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COMPRESSION LOADS IN EXCESS OF 3900 POUNDS ARE GUARANTEED. THE FLEXIBLE EXTENDED VINYL COVERING WEATHER SEALS THE CONDUIT AND RESISTS ABRASION AND CORROSION. THE METHOD OF SWAGING THE CADMIUM PLATED END FITTINGS PROVIDES GREATER TENSILE STRENGTH THAN HAS EVER BEEN OBTAINED IN BRAKE CABLES.
DETAILED INFORMATION AND ENGINEERING ASSISTANCE IS AVAILABLE ON REQUEST. SAMPLE CABLE ASSEMBLIES AND DRAWINGS WILL BE SHIPPED WITHIN 24 HOURS.
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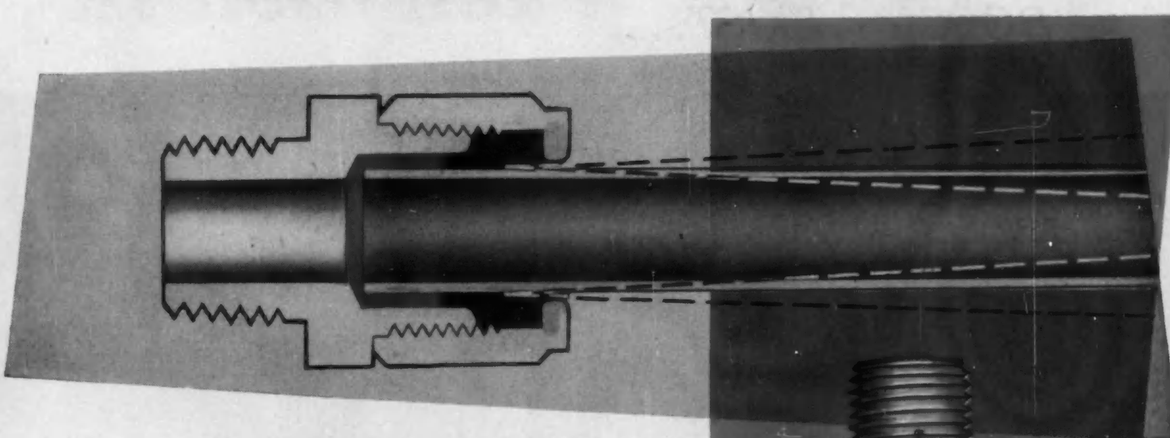

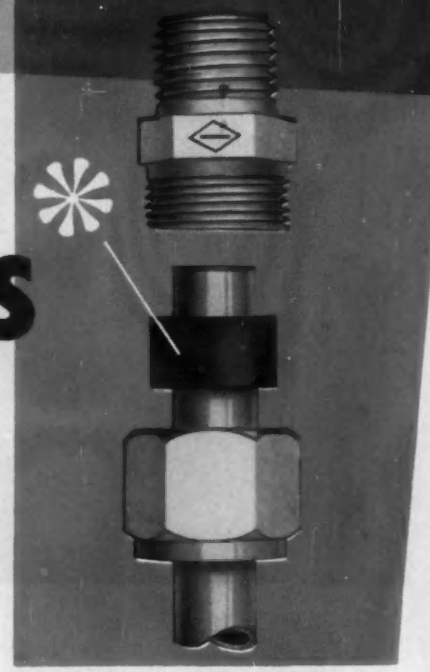

IMPERIAL FLEX® FITTINGS

are cushioned to end tube fitting failures!

Imperial Flex fittings thrive on vibration, mechanical shock and minor tube movement. Eliminate a common cause of fitting failure . . . and the need for costly flexible hose lines in many cases. In fact, if properly connected, Flex fittings will never fail under extreme vibration.

Speed installation too — Simply slip nut and sleeve over tubing. Insert tubing into body and tighten nut. That's all! Make pressure-tight joints on all seamed and seamless tubing, including scored tubing or tubing with surface defects. Can be disconnected and reconnected repeatedly without danger of leakage! Even slight misalignment will not cause leakage.

Built to take punishment — Proved superiority on severe applications is a matter of record. Forged bodies on elbows and tees are tough, rugged. Sleeve withstands gasoline and oil . . . flexes perfectly in sub-zero to 250°F temperatures.

Why Flex fittings can't fail

Like resilient mountings for automobile engines, Flex sleeve permits tube to flex back and forth through angle shown. Tubing can't wear because metal-to-metal contact is snubbed. Flex fittings are available for ⅛ to ⅞" O.D. tubing.

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For equipment that *might exist some day*. It means preparedness for the future. And for equipment entering the blueprint stage, it means Cleveland Graphite Bronze can offer improved designs and materials *right now*.

As a result, our field engineering teams, working in customers' plants, provide valuable assistance on the problem at hand combined with a sharp awareness of probable future requirements.

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FOR THESE AND 1001 OTHER APPLICATIONS, NEW R/M RAY-BOND ADHESIVES CAN BE TAILORED TO YOUR NEEDS

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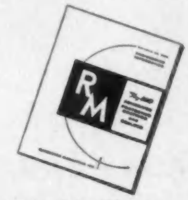
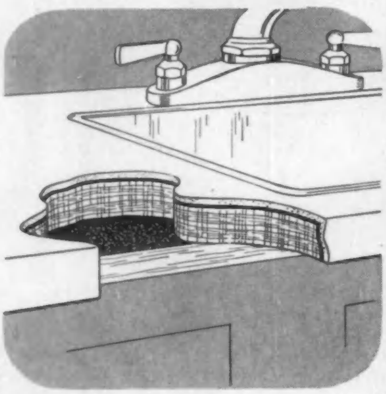
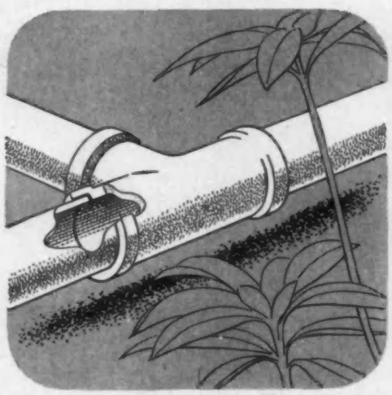
If bonding, laminating, sealing or coating can cut costs or improve production in your own operations, call on Raybestos-Manhattan engineers today.



R/M Bulletin No. 700 contains engineering information you will want on Ray-BOND adhesives, protective coatings and sealers. Write for your free copy.

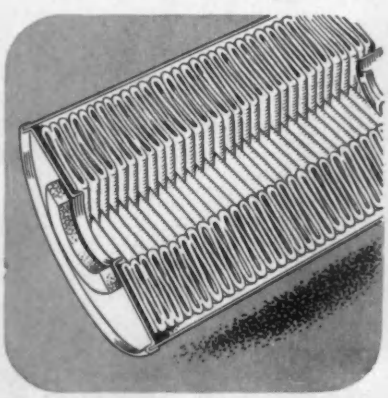


Bonding cabinet top to base.

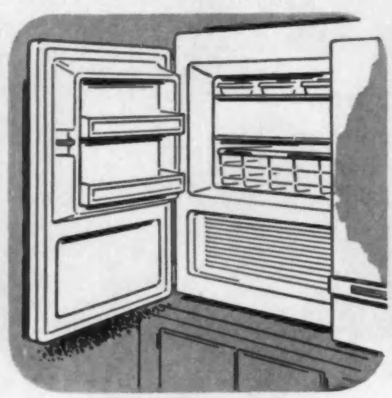


To create a firm bond on polyethylene plastic sewer and irrigation pipe.

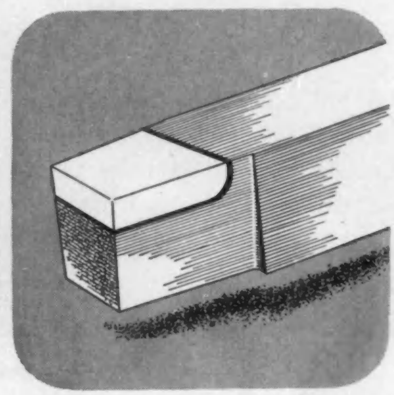
Bonding friction materials to metal.



Bonding paper to cork, aluminum or other metals for use in oil filter.



Bonding laminated panels of new plastic refrigerator.



Bonding ceramic tip to metal tool bit.

R/M

RAYBESTOS-MANHATTAN, INC.

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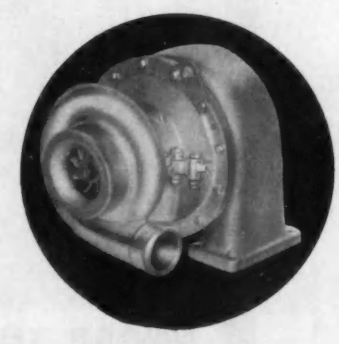

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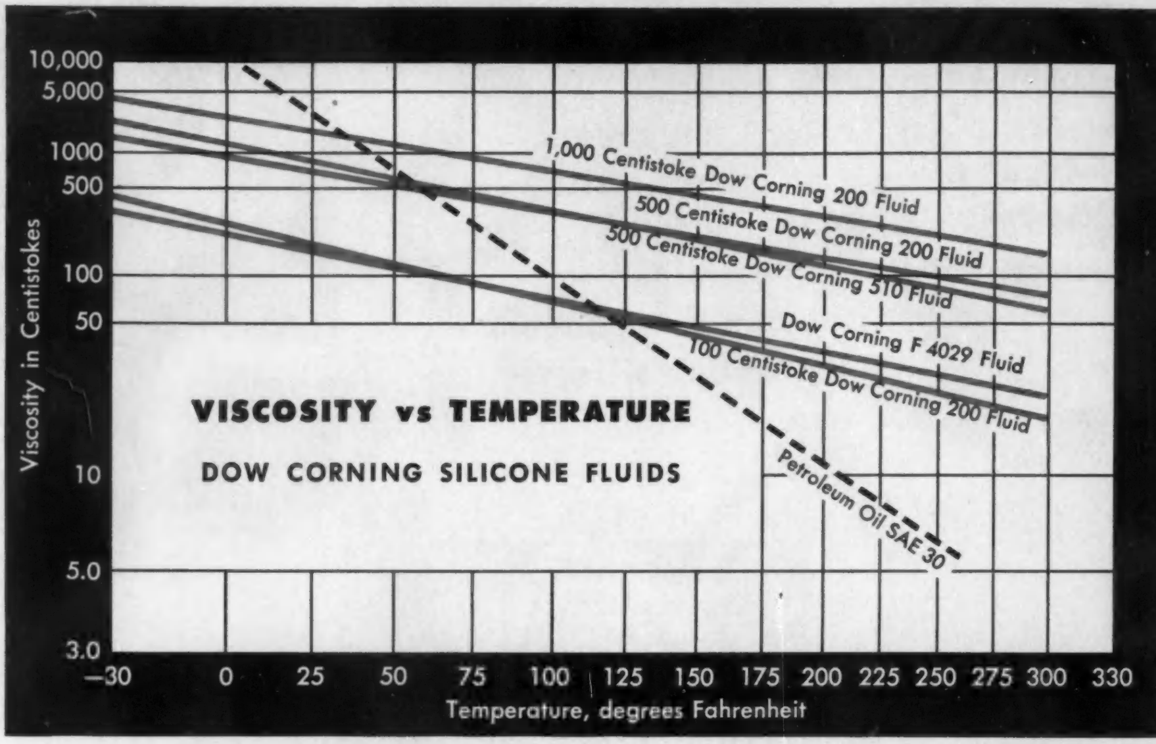

10,000
5,000
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5.0
3.0
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DOW CORNING SILICONE FLUIDS
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175
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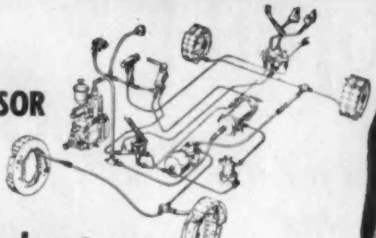

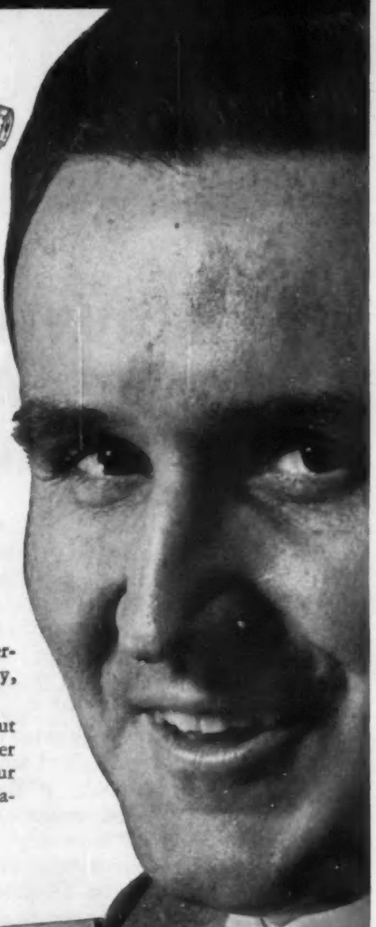

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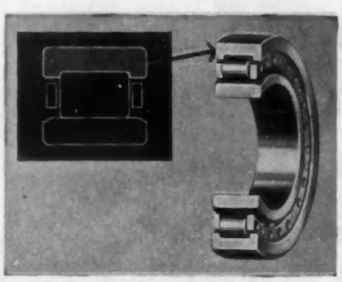

Now you can get standard sizes in C/R End Face Seals!

Chicago Rawhide now announces the availability of a complete new line of Standard End Face Seals to meet the widest possible range of sealing requirements. For sizes or conditions beyond the range of Standard End Face Seals, C/R engineers will continue to cooperate with you on special designs. Their experience in sealing applications is unmatched — your assurance of getting the correct seal for the job.

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Bulletin EF-100 includes complete envelope space data on C/R Standard End Face Seals and mating rings to help you select the correct size for your equipment design:

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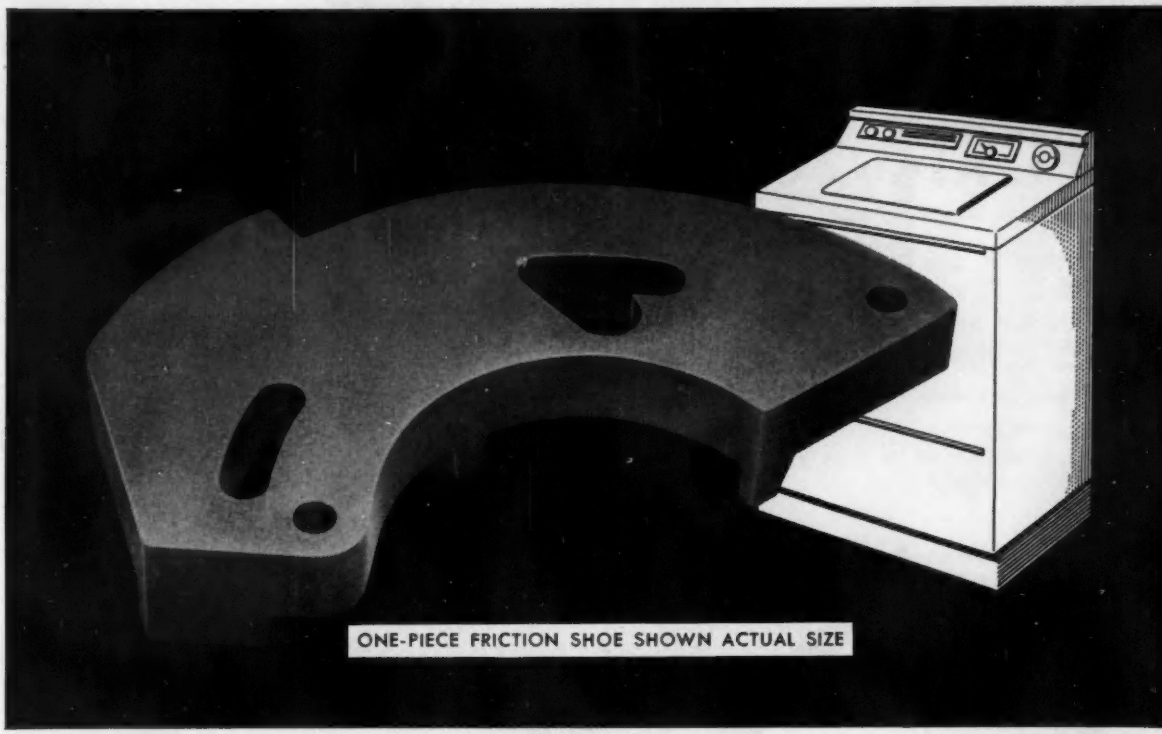
ANOTHER EXAMPLE OF HOW CONTINUING RESEARCH KEEPS R/M FIRST IN FRICTION



ONE-PIECE FRICTION SHOE SHOWN ACTUAL SIZE

R/M structural part made of friction material cuts costs 75%

This is a centrifugal clutch shoe for an automatic clothes washer. The old way you'd make it by bonding friction material to a steel member. R/M now makes it by molding the whole part of friction material—a special new type. And the manufacturer cuts the cost of the shoe 75%.

Cutting costs for customers is nothing new at Raybestos-Manhattan. We've been doing it for over 55 years. R/M has more extensive test facilities—and spends more on testing—than any other friction material manufacturer. Our many customers—prospects too—come straight to us for their own development testing. As a result we've amassed a wealth of knowledge about molded, woven, metallic and ceramic friction material behavior that is setting the pace for the industry.

Unlike other manufacturers, R/M works with all types of friction materials. Constantly testing, exploring, developing in advance of today's needs, R/M is finding new and profitable answers to friction problems you may be facing now. And with the number of sales engineers we have in the field, we can have a man at your desk on any problem within 24 hours.

Whatever your requirements, whatever your application, whenever you think of friction, think first of R/M.

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BATTERING CURB IMPACT TESTS PROVE NEW SUPER RAYON PREMIUM STRENGTH

- **Rayon cord is unsurpassed for impact resistance.**
- **Tire rims will be damaged by impact before rayon cord tires will.**

Those two facts are among the results established by extensive impact tests conducted by Motor Vehicle Research, outstanding independent testing authority, at South Lee, N. H.

Andrew J. White, director of the firm, concludes that under the rugged conditions of the carefully controlled impact test—more severe than the average driver would ever be expected to encounter—it would be inaccurate and misleading to claim that either rayon or other cord in general use possesses higher resistance to impact fracture.

The impact tests were conducted against a half-foot-high granite curbing. Adding to the severity of the experiment was prolonged driving that raised tire temperatures to over 200 degrees before impact.

There was not a single trace of cord damage, to either rayon or other cord, even though rims were badly bent, and the front ends of test cars often suffered severe damage. It was also found on detailed examination that the tires still had a great reserve before damage would result.

The 25 tires used in the research were four-ply, size 7.50 x 14, built by two leading manufacturers. In each case the tires to be compared in impact strength differed only in the reinforcing cord and in the cord adhesive.

The tires, heated to scorching temperatures through road runs and tight-circle turns, were slammed into the curbstone at 20, 40 and 60 miles per hour. As borne out by subsequent dissection and laboratory tests, the tires remained undamaged internally.

Analysis of the test tires, after the punishing blows of the curb, included measurement of tensile strength of fabric cords withdrawn from the section of the tire hitting the curb. Tensile strength of the cord after impact was essentially the same as the strength of the cords in unused tires.

The conclusion, as stated by MVR, is: "Dissection and close examination of a statistically significant number of identical tires manufactured with both rayon and other cord disclosed no cord damage in any tires. The test conditions are considered abnormal and are more severe than those found in general practice. Therefore the ability of rayon cord in tires to resist fracture from impact is clearly demonstrated and such ability is equal to other cord under these impact conditions."

For a copy of the complete report, write to us at the address below.

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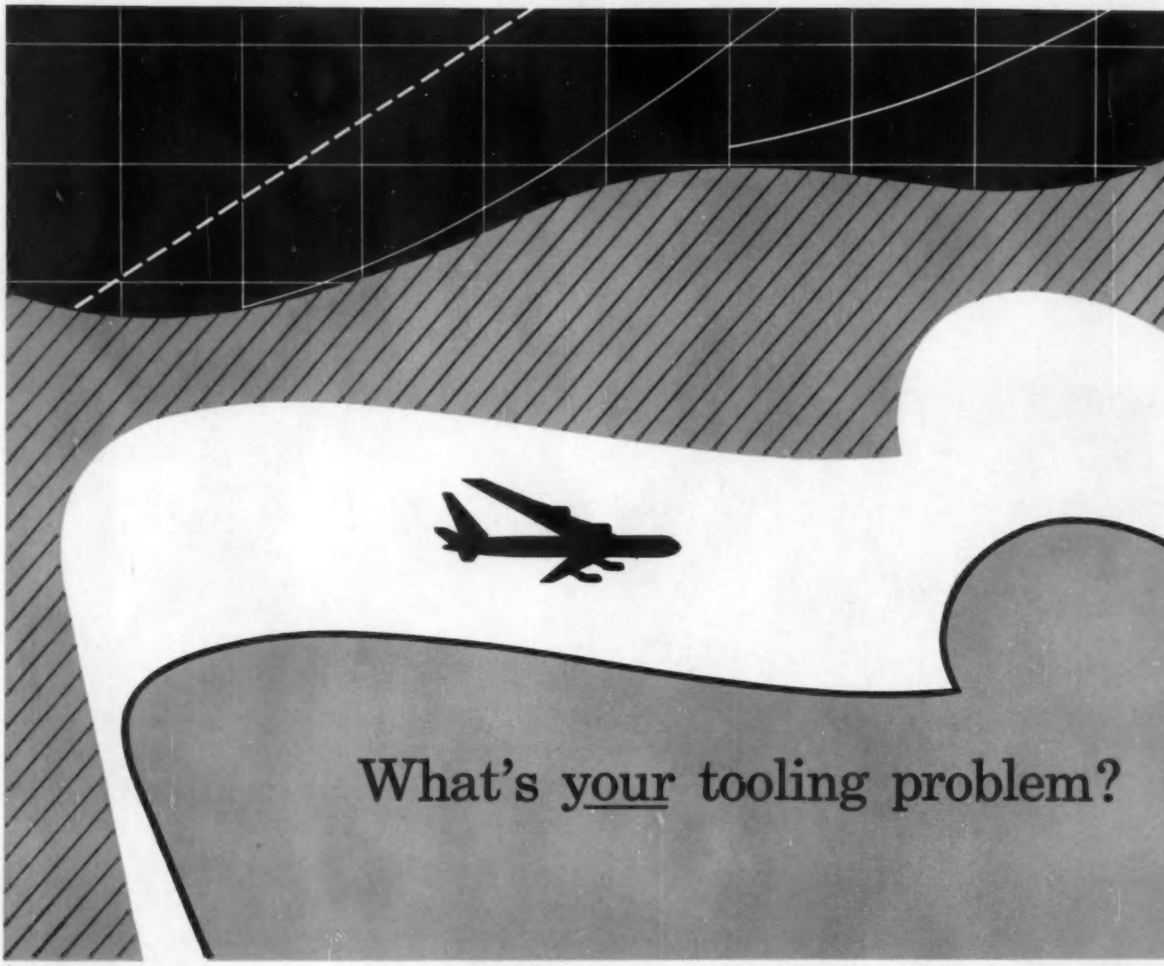

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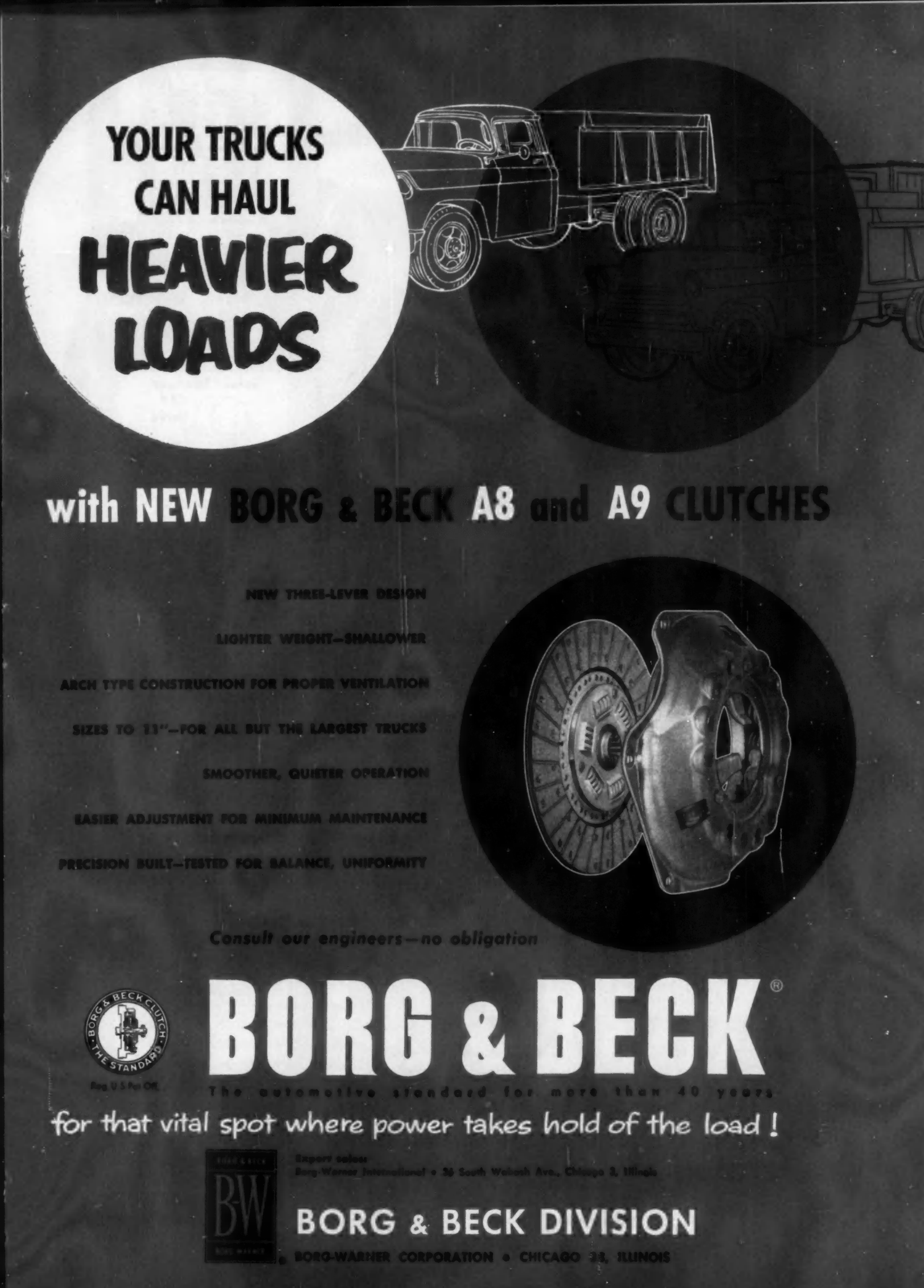
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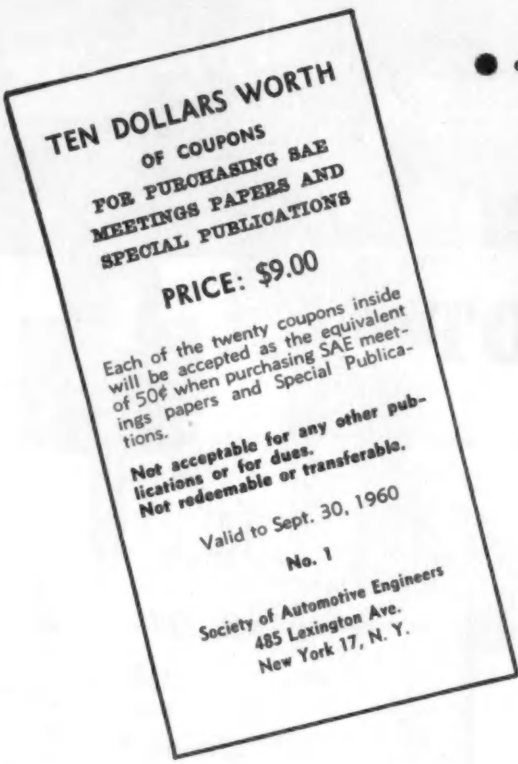
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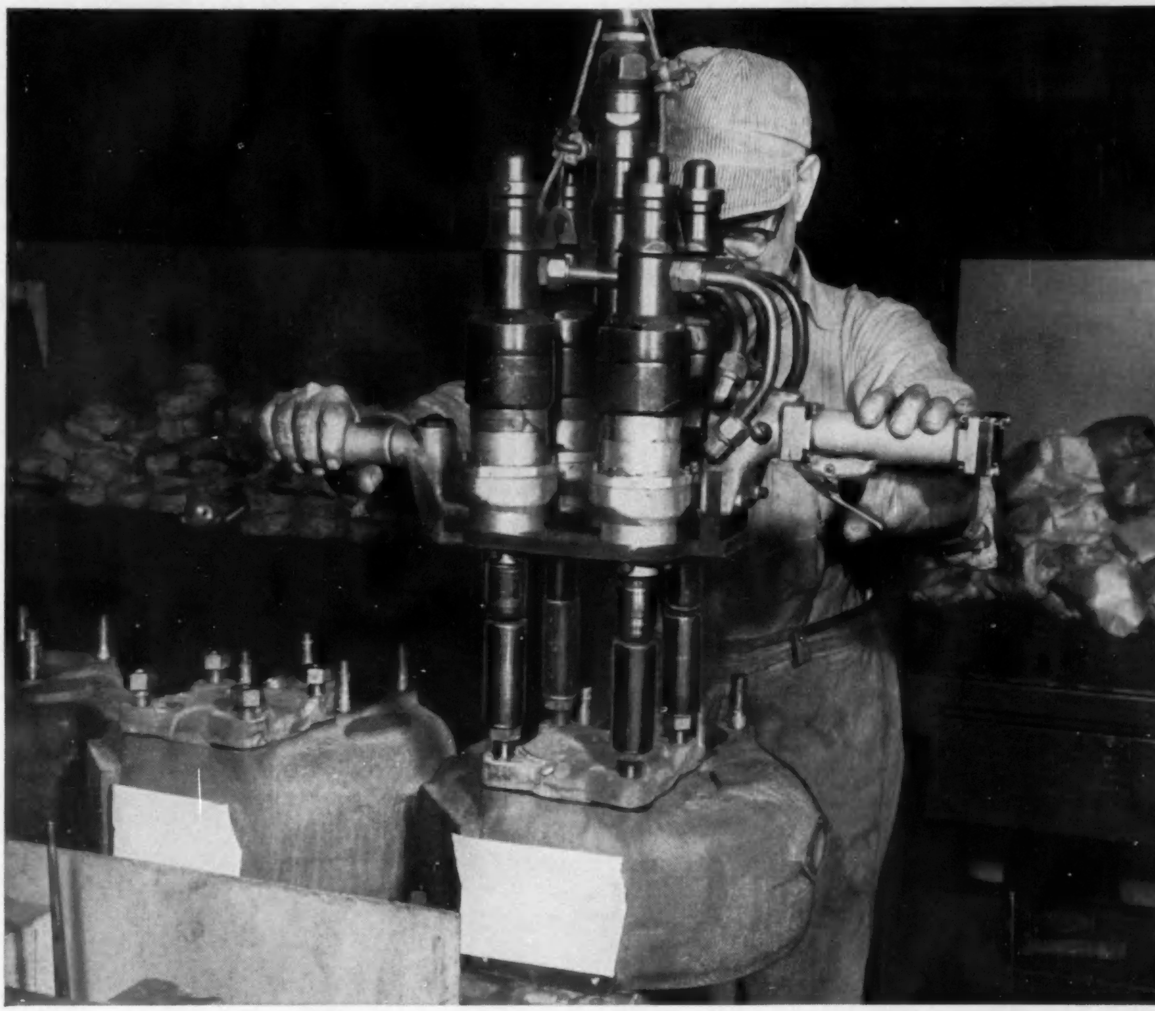

Four-spindle Gardner-Denver (Keller) multiple nut setter drawing up valve cover nuts on air compressor cylinder head—assures accurate torque control even on short production runs such as this.

Fast, accurate nut setting for any type production setup

Keep high-production pace

Increase the pace of your high-volume assembly lines with Keller multiple nut setters. They're fast—yet always accurate. You simply set them to the exact torque required . . . put them to work . . . forget them.

Made of standardized components, these versatile nut setters pay off in a hurry. They save time . . . are highly adaptable to a wide variety of jobs.

Speed low-production runs

For relatively low-production jobs such as the one pictured above, Keller multiple nut setters also cut time and costs. You run many nuts at once . . . assemble units faster. You eliminate manual torque wrench checks with accurate torque control . . . cut labor costs.

Standardized components make switching from job to job quick and easy. When the bolt pattern changes, simply move the standard spindles and handles to a new job-tailored mounting plate.

Very likely there are money-saving applications for Gardner-Denver's Keller multiple nut setters in your plant. Contact your Gardner-Denver representative for complete details.

ENGINEERING FORESIGHT—PROVED ON THE JOB
IN GENERAL INDUSTRY, CONSTRUCTION, PETROLEUM AND MINING

GARDNER-DENVER SINCE 1859 · KELLER TOOLS

GARDNER - DENVER

Gardner-Denver Company, Quincy, Illinois
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Aircraft Torque Wrench — Split Bearing Race — Pump Part — Slitter Knife — Machine Tool Part — Collet

For tricky shapes like these...

Steel that's hard and tough but easy to machine

PARTS like slitter knives, collets, split bearing races and the others shown above have to be hard and tough. But because of their intricate shapes, they have to be made of a steel that's easy to machine. This combination of toughness and machinability isn't easy to find. But you get it in Timken® 52100 steel.

Timken 52100 steel has a fully spheroidized structure that makes machining easy—without sacrificing strength or hardenability. It is a high-carbon analysis alloy steel with high fatigue and tensile strength and good hardenability throughout its cross section. Timken 52100 steel withstands working pressures up to 200,000 p.s.i., can be oil quenched to a maximum hardness of 65/66 Rockwell C in normal sections. And you can be sure of uniform quality in every shipment of Timken 52100 steel, because the Timken Company controls quality through every production step, from furnace to final inspection.

The Timken Company pioneered the production of 52100 steel tubing in the U. S. We're one of the world's largest producers of this hard, tough steel and the *only* source of 52100 steel in three finished forms—bars, tubing and wire. For small run or emergency requirements, we maintain a mill stock of 52100 tubing, in 101 sizes ranging from 1″ to 10½″ O.D. Write for a complete stock list of available sizes, grades and finishes. The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable: "TIMROSCO".

TIMKEN *Fine Alloy* STEEL

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